

1

**“Work safety in agricultural building, forest and
agro-food processes”**

International Conference: September 15-17, 2008 Ragusa - Italy
“Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems”

ORAL PRESENTATION

Control of the climate parameters inside greenhouses to defend workers health

Gusman A.¹, Marucci A.¹, Salvatori L.²

¹*University of Viterbo. DAF,*

Via S. Camillo de' Lellis – 01100 Viterbo, ITALY.

Tel 0039 0761357352, Fax 0039 0761357250, gusman@unitus.it

²*Specialist in Occupational Medicine*

Abstract

Greenhouse cannot be considered a very suitable place for work operators specially in hot season. Operators are forced to work in unfavourable conditions and exposed to harmful effects. Working at not suitable temperature combined with stress to the body from heavy physical activity, and exposure to chemicals, can be very dangerous to man's health.

The research was carried out to highlight the risks in the workers' health by analyzing the climate data recorded inside and outside the greenhouse in the Experimental Farm of the Agricultural Faculty of Viterbo from 1992 to 2002 in all season.

In addition to the calculation of WBGT index and of the human heat balance at different body temperature under various work conditions and clothing, the research also analysed the skip heat between internal and external environment on workers when they leave their worksite.

At 20th week the average of indoor temperatures is always above the limit suitable to operators and the average of maximum temperatures may rise as high as 40 °C at the 36th week.

The average values per week of WBGT index at the 16th week rose over the limit of 28 °C, considered standard limit as heavy work by current legislation.

In thermal stress conditions (>25°C) the amount of latent energy given off by sweat increased markedly reaching 60% at 30°C, 70% at 35°C and rose over 80% above air temperature of 40°C.

The paper is offered as a contribution towards evaluating the risks from long period of heat exposure.

Keywords: greenhouses, working environment, health risk.

Introduction

Greenhouse are structures utilized as microclimate environment to make the plants grow well in an favourable climate.

They are extremely useful when plants, in particular period of the year, cannot be grown in open country or in areas where the climate never guarantees a good quality crop. Vegetables need very high levels of temperature with a peak of 30 °C and 80 % of relative humidity but these levels cannot be considered favourable to operators who work in this environment.

Particular emphasis is placed on the risks to people who live in Mediterranean countries where the sun radiation can go over 1000 W/m². It is very difficult, in these regions, to control the excess of heat.

To prevent operators from taking periodic breaks during warmest months, it is necessary to control the temperature utilizing shading and common or mechanical ventilation systems.

Yet these precautions are not so enough to guarantee the health of operators forced to

work hard during the day.

Operators are exposed to two different kinds of stress: firstly the long time exposure to severe environmental conditions, according to the standards, secondly the thermal change, when they leave their work site

Prevention against chemicals disease has been the main focus of research but now climatic risks from exposure to heat environment is increasingly being recognised.

The paper is offered as a contribution towards evaluating the risks from long period of exposure at unfavourable environmental conditions into greenhouses that are bereft of artificial heating.

Legislative regulation

The first suggestions about microclimate in working environment date back to the legislative regulation n° 864 of September 19th 1970. In a generic way, the article n° 10 reports: "in the working places the temperature must be comfortable and stable as much as possible, according to the circumstances. The article n° 33 of the Legislative Decree n° 626 of September 19th 1994 and subsequent amendments (that substituted the article n° 11 of Presidential Decree n° 303/56) about the temperature in working places reports:

- 1) the temperature of inside environment must be suitable to operators during the work time according to their physical efforts and working methods.
- 2) A suitable and healthy climate must be well valued taking into account the influences of humidity and air movement.
- 3) The surrounding places such as, rest room, first aid room, surveillance room, canteens and toilets require a temperature suitable to their purposes.
- 4) Windows, skylight and glass walls must to prevent strong sun light from coming through specially during the working activity.
- 5) Specific protective measures and technical intervention reducing the level of risks are required as necessary when the temperature cannot be modified or when it is not cheap to modify the temperature..

The new unique legislative text about security and health of workers was issued on April 9th 2008 decree n° 81. The IV attachment "work place standards" taken, for the most part, from the legislative decree n° 626 of September 19th, lays down undetailed provisions about microclimate. In addition there is EU legislation utilized in Italy and synthetically laid down in the following table:

- UNI EN 27243: 1996 (ISO 7243) : Hot environment. Estimation of heat stress on working man, based on the WBGT-index (wet bulb globe temperature).
- UNI EN ISO 7933: 2004: Ergonomics of the thermal environment - Analytical determination and interpretation of heat stress using calculation of the predicted heat strain.
- UNI EN ISO 10551:2002.: Ergonomics of the thermal. environment - Assessment of the influence of the thermal environment using subjective judgement scales
- UNI EN ISO 7726: 2002 :Ergonomics of the thermal environment - Instruments for measuring physical quantities.
- UNI EN ISO 15265 2005: Ergonomics of the thermal environment - Risk assessment strategy for the prevention of stress or discomfort in thermal working conditions

Material and methods

The research was carried out in a tunnel structure in the experimental farm of Agricultural Science Faculty of University of Studies of Tuscia in Viterbo.



The semi elliptical tunnel is m 8.00 wide, 30.00 m deep and 3.40 m high (Fig. 1). The greenhouse structure is covered by a long life polythene film 0.18 mm thick. An electro fan, placed at the head back of tunnel, works governed by a thermostat keeping the temperature at 25 °C. The air (in taken from fan) entered the greenhouse through the window placed over the front door which is always opened in working time during the warmer months. There was no shading system. The plants were grown in four experimental patches.

Figure 1. Experimental tunnel

The instantaneous environmental parameters, on a 15 minute basis, was supplied by many sensors connected to a data logger Campbell CR 21, then stored in solid memories. Then, these data were gathered by a computer system for the next elaboration.

For this research were measured:

- the inside air temperatures at three levels (+50 cm, + 150 cm, +250 cm) in the centre of tunnel;
- the outside air temperatures into a meteorological station;
- the inside air relative humidity;
- the globe temperature.

Were taken into consideration the data recorded by 1992 to 2002.

The data measured by different sensors, on a year basis, were gathered weekly (from Monday to Sunday) to be compared with those registered by a thermoigrometer. There were n° 672 measurements per sensor (one per 15 min) per week giving us the minimum, medium and maximum weekly values.

The inside reference temperature data were obtained by taking an arithmetical mean of the data from the three sensors placed at three different levels.

The main purpose of research was, however, to identify the environmental conditions within the greenhouse during daily working hours. So it was performed another data processing, identical to the first calculation but limited to the data recorded in the period between the hours 8.00 am to 5.00 pm per day and per week, including Sundays.

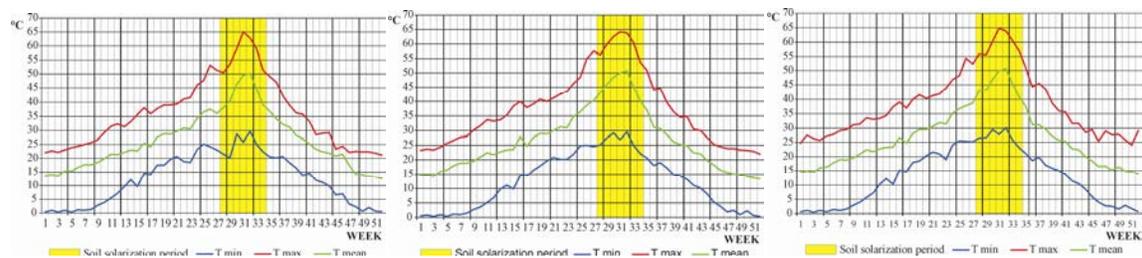


Figure 2. Inside air temperatures measured at + 50 cm, +150 cm and + 250 cm

The minimum, average and maximum values per week per each sensor so calculated were mediated with similar values of the years from 1992 to 2002 consequently we derived the weekly arithmetic means of minimum, medium and maximum inside temperatures at the

various heights of detection and the internal temperature of reference (average of three sensors) (Fig. 2). The same data processing was carried on the inside air relative humidity, black globe temperature and outside air temperature.

A further elaboration was covered about the calculation of the jump heat between internal and external at three levels of height in working time. With the same procedure we

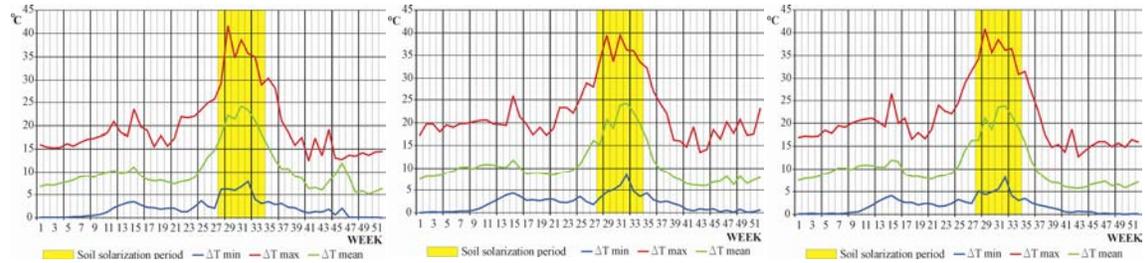


Figure 3. Jump between outside and inside temperature measured at + 50 cm, +150 cm and + 250 cm

have calculated the minimum, average and maximum thermal jump per week and per testing year.

The WBGT index was calculated using the inside reference temperature, the relative inside humidity and inside globe temperature on a 15 min. basis using this mathematical expression:

$$WBGT = 0,7 \cdot t_{wb} + 0,3 \cdot t_{bg}$$

where:

t_{wb} = wet bulb temperature [°C];

t_{bg} = black globe temperature [°C]

The work aims to have a detailed assessment of the greenhouse microclimate involving the characteristics of human body and its physiological implications.

In homeothermic condition, the energy given off by human body through the metabolism and the man/environment energy exchange in the form of thermal and mechanical energy must have the same value.

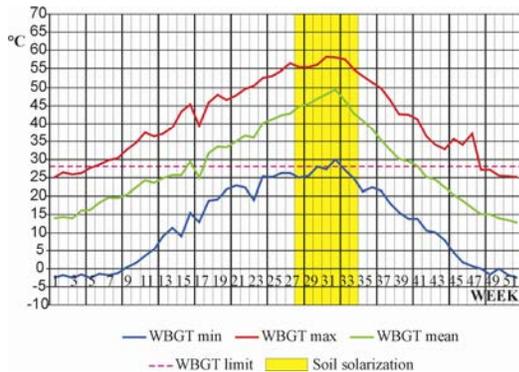


Figure 4. WBGT index

This is showed by the following formula:

$$M - W - E_d - E_{sw} - E_{ve} - C_{ve} - C - R - C_k = 0$$

where:

M = thermal power given off by body for metabolism,

W = power exchange between man and environment in the form of physical work,

E_d = latent thermal power given off by body surface,

E_{sw} = latent thermal power given off by perspiration;

E_{ve} = latent thermal power given off by respiration;

C_{ve} = sensible thermal power given off by respiration;

C = thermal power given off by convection;

R = thermal power given off by irradiation,
 C_k = thermal power given off by conduction.

1. thermal power realised by the body for metabolism

$$M = 351 \cdot (0.23 \cdot RQ + 0.77) \cdot V_{O_2} \text{ [W/m}^2\text{]}$$

2. power exchange between man and environment in the form of physical work

Mechanical power given off by work activity calculated considering the mechanical efficiency $\eta=0.2$

3. latent thermal power given off by body surface

$$E_d = 3.05 \cdot 10^{-3} \cdot f_d \cdot (1 - \omega) \cdot A_b \cdot (256 \cdot t_{sk} - 3373 - \phi \cdot p_{as}) \text{ [W]}$$

4. latent thermal power given off by perspiration

$$E_{sw} = \lambda \cdot f_d \cdot k' \cdot \omega \cdot A_b \cdot (x_{sk} - x_a) \text{ [W]}$$

5. latent thermal power given off by respiration

$$E_{ve} = 1.72 \cdot 10^{-5} \cdot M \cdot (5867 - \phi \cdot p_{as}) \text{ [W]}$$

6. sensible thermal power given off by respiration

$$C_{ve} = 0.0014 \cdot M \cdot (34 - t_a) \text{ [W]}$$

7. thermal power given off by convection

$$C = f_{cl} \cdot h_c \cdot A_b \cdot (t_{cl} - t_a) \text{ [W]}$$

8. thermal power given off by irradiation

$$R = 3.96 \cdot 10^{-8} \cdot f_{cl} \cdot A_b \cdot \left[(t_{cl} + 273)^4 - (t_{mr} + 273)^4 \right] \text{ [W]}$$

9. thermal power given off by conduction

C_k = not important for this balance

<p>RQ = Respiration rate (between volume CO_2 given off and Vol O_2 given in) V_{O_2} = Volume of oxygen consumption [l/min] at $T=0^\circ$ $P=1$ atm f_d = permeability factor of clothing ω = body area covered by sweat perspiration (area of wet surfaces sweat/body surface area) A_b = body surface area [m^2] $A_b = 0.202 \cdot m^{0.425} \cdot h^{0.725}$ (Du Bois) m = body weight [kg] h = body high [m]. t_{sk} = mean skin temperature [$^\circ C$] ϕ = relative humidity p_{as} = vapour pressure at air saturation [Pa] k' = mass transfer coefficient [$kg/(m \cdot s)$] $k' = h_c / 1.012$</p>	<p>h_c = unit conductivity air/clothes [$W/(m \cdot K)$] x_{sk} = specific humidity insaturation condiction at skin temperature [$kgwater/kgdry$ air] x_a = specific humidity of the air [$kgwater/kgdry$ air]. t_a = air temperature [$^\circ C$]. f_{cl} = relationship between external surface area of clothes A_{cl} [m^2] and surface area of the naked body A_b [m^2]; h_c = convective unit conductivity clothes-air [$W/(m \cdot K)$]; t_{cl} = mean temperature of external surface of dressed human body [$^\circ C$] t_{mr} = mean radiant temperature of the environment [$^\circ C$]</p>
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

The human body heat balance was evaluated at 6 different air temperature: 20 $^\circ C$, 25 $^\circ C$, 30 $^\circ C$, 35 $^\circ C$, 40 $^\circ C$ and 45 $^\circ C$.

Results

a) Inside air temperature

At the high of 150 cm (man height) in working time the inside air average temperatures

always remained above 20 °C in the period between the 8th and the 45th week and in the period between the 19th and the 37th week reached 30 °C. Starting from the last weeks of June, this value exceeded 40 °C¹.

Though the standards do not lay down exact limits of the inside air temperature it has been assumed that the optimal temperature normally should not exceed 25 °C.

For a period of 20 weeks, the average of inside air temperature is always above the reasonable limit suitable to operators.

About the average of maximum inside air temperature, the period is n° 16 weeks longer than the just said period of the average temperature.

In this period the temperatures may rise as high as 40 °C; these high values were recorded about midday when normally operators keep working.

A long exposure to these high temperatures may cause thermal stress² with the following consequences:

- Heat Rash (prickly heat);
- Radiation Burns (Sunburn);
- Transient Heat Fatigue;
- Heat Syncope;
- Heat Cramps;
- Heat Exhaustion;
- Heat Stroke;
- Indirect Heat-Related Health Effects;

Or long term effect:

1. Reduced Work Performance: tired, fatigued workers perform with reduced accuracy, efficiency;
2. Increased Accidents: tired, fatigued workers are more susceptible to accident and injury;
3. Reproductive Problems: heat has been shown to reduce both male and female fertility and may be a problem for the fetus;
4. Heart/Lung Strain: if you already have heart, lung, kidney or circulatory problems; heat stress is an added strain on your body which in severe situation may precipitate serious episodes of acute problems.

On the contrary, the minimum values of the inside air temperature falls down as low as 0 °C in the first week of the year. This condition, though uncomfortable, does not cause risks for health's operators who can wear heavy clothes to protect themselves from cold.

The graphs shows that the temperature values at a high of +50 cm (plants level) and at a high

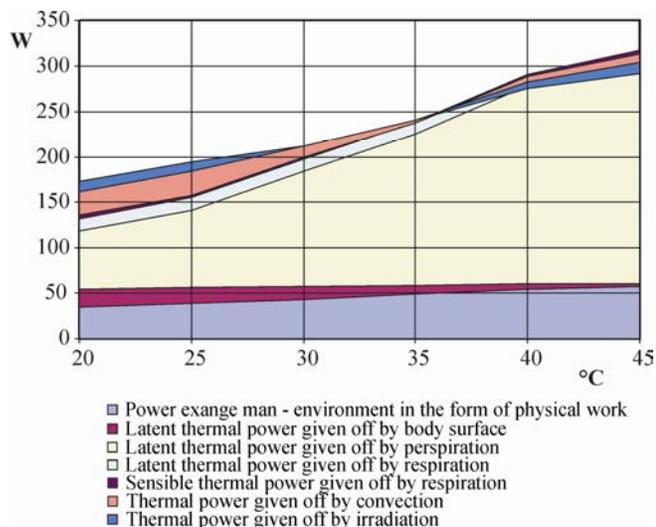


Figure 5. Power losses from human body

¹ It is not considered the period between the 28th and the 34th week because the greenhouse was closed for soil solarization.

² Heat Stress is defined as the physical and physiological reactions of the worker at temperatures that fall outside the normal comfort zone of workers.

+ 250 cm (near the cover film) don't seem have a significant difference from values measured at + 150 cm. This is due to mechanical ventilation that makes the temperature homogeneous.

b) Thermal jump between inside and outside air

About thermal jump, the figures showed that the average of the difference between inside (at + 150 cm) and outside temperature is constant about 10 °C in the first period of the year till the soil solarization and not worrying for operators who leave the worksite.

Also the maximum of thermal jump did non seem to give problems to health's man till the 21st week because the temperature remained on the average of 18°C. Starting from the June period the maximum of thermal jump rised as high as 30 °C. These high values could generate some problems about breathing to operators without same precaution (thermal filter room).

c) The WBGT

The WBGT, an index widely used for the assessment of indoor environment, was estimated taking in account the average of inside air temperature, the humidity rate and the temperature measured by black globe thermometer.

The average value per week, during the test period, at the 16th week rose over the limit of 28 °C, considered by current legislation as standard limit for moderate work.

Into the greenhouse operators' work is not supposed to be "heavy" according to labouring standards, yet the some positions of operators, as handwork at soil level, could be very dangerous. For this reason the greenhouse operation should be classified as the "heavy work". Assuming, however, the limit of 28°C valid for acclimatized³ workers with suitable summer clothes, it is observed that the average values of WBGT exceeds the standard limit from the 16th week up to the 41st week, except the soil solarization period. The highest of average values are above 40°C before the soil solarization period and the average of inside air

Table 1. Human heat balance [W]

Human heat balance	Inside greenhouse air temperature [°C]					
	20	25	30	35	40	45
Input: <i>M</i>	172.4	194.4	216.7	246.0	269.2	286.1
<i>W</i>	34.5	38.9	43.3	49.2	53.8	57.2
<i>E_d</i>	19.9	17.0	14.1	9.2	6.3	2.9
<i>E_{sw}</i>	64.1	84.9	126.5	167.0	218.6	247.7
<i>E_{ve}</i>	13.9	14.3	13.9	12.9	11.8	10.0
<i>C_{ve}</i>	3.4	2.4	1.2	-0.3	-2.3	-4.4
<i>C</i>	26.2	26.2	13.0	3.1	-6.2	-9.3
<i>R</i>	10.5	11.1	0.0	0.0	-7.3	-12.7
Total output	172.5	194.8	212.0	241.0	274.8	291.4

temperatures goes over 35°C.

The inside environment, of course, becomes particularly dangerous around the central hours of the working day (Fig.2)

The minimum values, always remain below the standard limit therefore do not cause problems for the health of employees.

d) Human heat balance

Analyzing the results of human heat balance (table 1), in the different conditions (from 20 °C to 45 °C) it appears that whereas the thermal power given off by work activity remains

³ Acclimatization requires up to 3 weeks to be fully established and is noticeably decreased after 4 days (for TLV® purposes: use 5 of last 7 days)

constant (mechanical efficiency $\eta=0.2$) the power given off by body, in different ways, varies in according to the air temperature variations.

In welfare conditions the most loss of energy occurs by perspiration (37 %), by convection (15%) and by diffusion from skin (11,5%). The energy loss in other way was about 10 %.

But about the higher limit of welfare parameters (25°C) the power given off by perspiration rises till 43.6% .

In thermal stress conditions ($t_a > 25$ °C) the amount of latent energy given off by perspiration increases markedly reaching 60 % at 30 °C, 70 % at 35 °C and rises over 80 % above the temperature of 40 °C.

Perspiration has a very important role to guarantee the human heat balance in stress conditions. Water given off in the form of perspiration or breathing rises with the increase of

Table 2. Water losses through perspiration and respiration [l/h] temperature (table 2).

Water	Inside greenhouse air temperature [°C]						The amount of water given off by perspiration increases and is above 300 g/h when the air
	20	25	30	35	40	45	
<i>Perspiration</i>	0.091	0.120	0.178	0.234	0.305	0.344	temperature
<i>Respiration</i>	0.020	0.020	0.020	0.018	0.016	0.014	2).

temperature is over 40 °C. Undoubtly the water loss produces an alteration of the body water equilibrium with a consequent loss of minerals, leading workers to severe health risks.

Conclusion

The analysis of different climatic parameters and the results of data processing of the WBGT and of the thermal human balance have shown that for a long period of year the inside climatic conditions are above a reasonable level of comfort for operators. Both the air temperature values and the WBGT show clearly that the human body is stressed in a non-appropriate mode even for subjects acclimatized.

Indeed, analysis of the thermal human balance of a standard person in average environmental conditions, calculated in terms of WBGT, shows a loss of thermal energy trough a remarkable perspiration and breathing with a consequent loss of water and mineral salts that could lead to the immediate and remote serious consequences as heat syncope.

The technological solution to avoid these dangers lies, in our opinion, in drastic reduction of solar energy during the hottest periods of the year. But this solution is not always possible to apply in the intermediate seasons when the solar energy constitutes the main sustainable source of energy for the greenhouse productions.

However, many heat related health problems can be prevented or the risk of developing them deduced by some precautions.

To take advantage of climatic conditions operators should work earlier in the morning or in the coolest times of the day.

Clothing should be appropriate, shifting the working time when heavy and uncomfortable dresses are unnecessary. Operators, during the hot working time should be forced to have fresh drinks bereft of glucose and rich in minerals to replace the loss of thermal energy.

Could be useful to minimize exposure to high temperature and sun but this is not always possible when sun is the main source to make the plants grow.

To take advantage of climatic conditions operators should work earlier in the morning or in the coolest times of the day.

It is understandable discomfort of a prolonged interruption but the advantage on the

health of employees has a value much greater.

Thermal jump does not seem to be particularly dangerous for worker health when leaves worksite.

Even in the most serious jump temperature may be borne by workers with simple and elementary shrewdness as protection with dry clothing or going through areas filter at intermediate temperature (eg room appropriately shielded).

The greenhouse is an important source for Italian agriculture because it provides an environment conducive to plants production on a year-round basis or extend the growing season. Yet a greater overall knowledge and preventive measures would all help the operators to avoid risks of indoor work.

References

ALFANO G., d'Ambrosio F.R., Riccio G. 1998 . Disagio e stress termico: effetti, normative, valutazione e controllo. dBA 98 "Dal rumore ai rischi fisici". Modena, 1998, 531-566.

Monarca D., Cecchini M., Marucci A., Porceddu P.R. 2003. Microclimate Risk for Workers in Greenhouses. XXX CIOSTA - CIGRV Congress, Turin, 22-24 September 2003.

L. 19 ottobre 1970, n. 864. Ratifica ed esecuzione delle Convenzioni nn. 91, 99, 103, 112, 115, 119, 120, 122, 123, 124 e 127 dell'Organizzazione Internazionale del Lavoro.

Decreto legislativo n.626 del 19 settembre 1994. Attuazione delle direttive 89/391/CEE, 89/654/CEE, 89/655/CEE, 89/656/CEE, 90/269/CEE, 90/270/CEE, 90/394/CEE, 90/679/CEE, 93/88/CEE, 95/63/CE, 97/42/CE, 98/24/CE, 99/38/CE, 99/92/CE, 2001/45/CE, 2003/10/CE, 2003/18/CE e 2004/40/CE riguardanti il miglioramento della sicurezza e della salute dei lavoratori durante il lavoro.

DECRETO LEGISLATIVO 9 aprile 2008 , n. 81. Attuazione dell'articolo 1 della legge 3 agosto 2007, n. 123, in materia di tutela della salute e della sicurezza nei luoghi di lavoro.

UNI EN 27243: 1996 (ISO 7243) : Hot environment. Estimation of heat stress on working man, based on the WBGT-index (wet bulb globe temperature).

UNI EN ISO 7933: 2004: Ergonomics of the thermal environment - Analytical determination and interpretation of heat stress using calculation of the predicted heat strain.

UNI EN ISO 10551:2002.: Ergonomics of the thermal. environment - Assessment of the influence of the thermal environment using subjective judgement scales

UNI EN ISO 7726: 2002 :Ergonomics of the thermal environment - Instruments for measuring physical quantities.

UNI EN ISO 15265 2005: Ergonomics of the thermal environment - Risk assessment strategy for the prevention of stress or discomfort in thermal working conditions

Land Rover fire truck modernization for improving transportation needs of the forestry farms and tree nurseries

Dubowski A. P.¹, Pawlowski T., Weymann S.

PIMR - Industrial Institute of Agricultural Engineering

Starolecka 31, 60963 Poznan, Poland, +48618712222, +48618793262, ¹ad@pimr.poznan.pl

Abstract

In Poland farm tractors with trailers are used in forestry transportation work. Most of these trailers are equipped with dangerous one line pneumatic or inertia brake system.

The works done by PIMR-Industrial Institute of Agricultural Engineering and University of Life Sciences in Poznan [2] indicate needs for new set of trucks and gooseneck trailers, which should be designed for transportation use in forestry. Such modern forestry transportation unit should be equipped with new category of ball hitch and coupler, electronic braking system in gooseneck trailer and tyres - rated up to 90 kmph.

PIMR's idea was to transform Land Rover Defender [LRD] fire truck into mini forestry tractor for towing gooseneck trailer (gross trailer weight 3.5 tones). In 2007 LRD was equipped with 60 mm hitch ball for gooseneck trailers. Height of ball hitch over trucks floor allows easy mounting fire module. To transform fire truck into mini-tractor - fire module should be taken off then gooseneck trailer should be coupled on hitch ball, as well as light and electronic Sens A Brake System (SAB) plugs connected with proper sockets. Reversing procedure allow to transform forestry mini-tractor into fire truck.

Modernizing fire trucks should have immediately impact on better vehicles management and more efficient exploitations of trucks in forestry farms and tree nurseries.

Expected to obtain results 1) more efficient exploitation of fire trucks, 2) better work environment for driver, 3) general improvement of road traffic flow, 4) potential new job position market for rural and small town society.

Keywords: gooseneck trailer, hitch ball, electronic, hydraulic, brakes, safety.

Introduction

In Poland farm tractors with trailers are used in forestry transportation work. Most of these trailers are equipped with dangerous one line pneumatic or inertia brake system (Dubowski 2005). Very often forestry trailers (gross vehicle weight up to 13 tones) are not equipped in any brake system. Explanation that is usually heard from forestry drivers - it is because such trailers are not moving on public road system but on excluded forestry roads and of course it is not true.

The works done by PIMR-Industrial Institute of Agricultural Engineering and University of Life Sciences in Poznan indicate needs for new set of trucks and gooseneck trailers, which should be designed for transportation use in forestry (Dubowski 2002).

Such modern forestry transportation unit should be equipped with new category of ball hitch and coupler, electronic braking system in gooseneck trailer and tyres - rated up to 90 kmph (Dubowski 2007).

The adaptation of the Land Rover trucks, which are presently used mainly to quench fire in forests, should extent to the range of possible applications e.g. for the transport of trees from container nurseries to the area of new forestry fields, for wood transport on narrow forest ducts without using heavy forestry truck units, which devastate forest ways, and for the transport tanks with water (Dubowski 2003).

PIMR and Regional Biuro of the State Forests NFH co-operation

General idea of new transportation system for forestry trees nursery

Several meetings at Regional Biuro of the State Forest National Forest Holding (SF NFH) in Zielona Gora and its Forestry Department (Nadlesnictwo) in Babimost underline needs for research support from PIMR-Industrial Institute of Agricultural Engineering in Poznan. One of the most important issue that should be workout in near future is design of modern transportation system for new Forest Tree Nursery (fig. 1) located in small village Rogoziniec, Poland. Few years ago it was build as modern nursery unit with several tents for grow of trees in Styrofoam block containers. Containers (65x32x19cm) are made of expanded polystyrene foam and contain 53 or 74 cylindrical cavities or cells that are arranged in regular pattern (fig. 2).



Figure 1. Forest Trees Nursery - tent for growing trees in block containers



Figure 2. Styrofoam block containers with 53 cells for growing forest trees

By the methods which are used at the moment the time of loading block containers on truck and trailer is very long as well as time of unloading that is made by forestry workers.

Preliminary agreement ideas were 1) to use Land Rover Defender fire truck coupled with small gooseneck trailer, 2) to use wood pallets (2x2 m) each with 36 block containers (each container ~11kg and pallet ~450 kg of total weight) that at nursery site will be loaded by forklift truck and in the planting site will be unloaded by gooseneck trailer's hydraulic lift. During transportation forest trees should be protected against wind, heavy rain and sun so gooseneck trailer's load-carrying body should be protected by canvas cover.

In Poland fire trucks are used for fire service only seasonally from late spring till autumn so after ten years of service the average mileage is 50 thousands km. Out of fire season (early spring and late autumn) these trucks coupled with light gooseneck trailer could serve as mini liners for forest trees nursery transportation needs.

Design of special support frame for hitch ball and montage of Sens A Brake system in LRD
PIMR's idea was to transform Land Rover Defender [LRD] fire truck into mini forestry tractor for towing gooseneck trailer (gross trailer weight up to 3.5 tones). Two issues should be solved and well design – it is special support frame of hitch ball and montage of electronic Sens a Brake (SAB) system in the truck cabin (Dubowski 2007).

In 2007 LRD was equipped with special support frame of hitch ball for gooseneck trailer (fig. 3-4). Height of 60 mm ball hitch over trucks floor allows easy mounting fire module (fig. 5).



Figure 3. Support frame of hitch ball



Figure 4. Anchor plate with main beam



Figure 5. Land Rover Defender - 60mm hitch ball for coupling gooseneck trailer

To transform fire truck into mini-tractor - fire module should be taken off then gooseneck trailer should be coupled on hitch ball, as well as light and SAB System's plugs

connected with proper sockets. Reversing procedure allow to transform forestry mini-tractor into fire truck.

Montage of SAB system (EI Ltd. 2007) in the fire truck cabin was difficult and challenging because of lack of enough free space under dash board and overcrowding shelve with GPS receiver and several radio/mobile phone units with special services channels (forestry services, fire/medical channel). Mouse was located on the top of the dash board and electronic control unit (EVO) was placed on the small support plate mounted to the edge of wall just very next to acceleration pedal (fig. 6).



Figure 6. Brake Pad mounted on brake pedal and EVO controller on support plate.

Preliminary road and field test results

Laboratory research and preliminary road and field tests of Land Rover Defender 110 fire truck and PIMR's research gooseneck trailer GN2000 (GVW 3780 kg) proved that such road unit can easily transport goods on unpaved rural and forestry roads (fig. 7).

Research analyses that were run in the 2007 and 2008 year changed few issues of preliminary future gooseneck trailer's concept and pallet design. First homologation tests run on agricultural type of tires XP 27 275/65 R16 (recommended by Michelin Poland) were surprisingly to soft – so after two harsh braking they lost 6mm of groove's height and they were not able to achieve 0,5g deceleration. In addition all of four tires were dynamically unbalanced (190-200g). E-mail letters to main quarter of Michelin, France with PIMR kind request of support and cooperation were left without any reply. Polish branch of Michelin returned us money for four tires but managers strongly defend its product as one of the best in the field.

Despite Michelin Poland Product Manager's firm statements about tires European homologation - PIMR can not confirm good quality of XP27 tires and we would not recommended such low quality products for use in agricultural and forestry gooseneck trailers. PIMR is still searching for very good quality of agricultural/forestry type of tires (16-17,5 in size) with speed index 70-90kmph, air pressure about 3-4 bar and load per axle 3, 5 and 9 tones.



Figure 7. LRD 110 with research gooseneck trailer GN on forestry road.

Forest trees transportation system general outline

New trees transportation system general outline is based on smaller pallets which loading space will be 130x65cm and will be made of wood or steel. Each pallet will be equipped on both sides with additional frame structures for lifting and unloading such pallet container in the planting sites. Weight of container will be ~ 220kg. To protect forest trees roots against desiccation (dry out) each pallet container will be protected by individually mounted canvas cover - closely tighten to the side walls of the steel container frame. These allow to resign from idea of use small hydraulic lift and replace it by manually operated lift, located in the front of gooseneck trailer loading space and integrated with frame of its tongue.

Design of new pallet containers and innovation unloading system will be workout in 2008 year thanks R&D project NR10000604 supported by governmental funds of National Research and Development Centre in Poland (NCBIR 2008). Thanks that 36 months project will be design, developed and tested new transportation system based on box trucks and gooseneck trailers. New road units equipped with innovative types of coupling devices and brake by wire (BBW) electronically steered hydraulic brakes in towed vehicles - should have great impact on improving work safety, efficiency of transportation and reducing congestion on Polish roads network. Specialized gooseneck trailers should reduce human work, improve quality, safety and efficiency of agricultural and forestry transportation. New technology will be a chance for new job positions market and this is very important for rural and small town society.

Conclusions

1. Modernization of Land Rover Defender 110 fire truck was successful and forestry road tests has shown very good traction especially during towing gooseneck trailer – GVW 3780 kg on forestry and rural unpaved roads.
2. Elements of Sens a Brake system are functionally and ergonomically well located in truck cabin and electric wires are securely mounted under LRD fire truck body.
3. Design of 60mm hitch ball support frame is done well and could be only improved by expandable hitch ball version for regular LRD trucks that are used for forestry patrolling.

4. New gooseneck trailer should have wheels thread similar to LRD truck, GVW 3-3,5t and should be equipped with new forest trees transportation system based on medium size pallet containers, each with canvas cover for better forest tree protection against desiccation.
5. Tires should be much better quality than agricultural type tires XP 27 275/65 R16 and should be tested in tough research tests on unpaved forestry and agricultural roads as well as on public road network. It is important that wear of tires should be lowest as possible because trailers with GVW up to 3,5 t do not need to be equipped with ABS system.
6. New forestry transportation units based on light trucks and gooseneck trailers should improve exploitation of fire trucks that are used in Regional Departments of State Forest National Forest Holding as well as should improve work safety, forest trees transport quality and efficiency.

References

Journal Paper:

Dubowski A.P., Weymann S. 2007. Adaptation of fire truck to tow gooseneck trailers for better and more effective use in forestry service. *Technika Rolnicza Ogrodnicza Lesna*, 6, 11-13, 2007

Chapter in book:

Dubowski A.P., Wojtkowiak R., Kromulski J. 2003. New category of agricultural semitrailers adapted for connecting with both farm tractors and box trucks. *Scientific Network AGRORISKS – Elimination of agricultural risks to health and environment*. Edited by Andrzej Myczko. *Papers from Members of AGRORISKS Network*. 155:162, Poznan. 2003.

Dubowski A.P., Wojtkowiak R. 2002. Possibility of adaptation light trucks semitrailers and trailers equipped with electric brake system for use in forestry. *PAN Dept of Agricultural, Forestry and Veterinarian Sciences. Zeszyty Problemowe Postepow Rolniczych. Zeszyt 486 Czesc 1, 261:268, Warszawa, 2002.*

Conference Proceedings:

Dubowski A.P., Pawłowski T. 2005. Medium size road units - an innovative approach for improving efficiency and safety of agricultural transportation in Poland and Europe as well. *XXXI CIOSTA- CIGR V Congress Proceedings: Increasing work efficiency in agriculture, Horticulture and forestry*. Hohenheim, Germany, 154:161 19-21 September 2005.

Dubowski A.P., Pawłowski T. 2007. Elektroniczny układ hamulcowy dla nowej generacji środków transportu, zwłaszcza rolniczego. *CD-ROM Prace naukowe „TRANSPORT” Nr 1(25)/2007*. *International Conference LogiTrans2007, Szczyrk, Poland, 25-27 April 2007.*

Website:

Edge International Ltd. 2007. www.sensabrake.com/downloads/brochure.pdf

NCBIR 2008. www.ncbir.pl/www/

Small dairies design to improve safety and workers' welfare in mountain areas

Dioguardi L., Sangiorgi F.

University of Milan. Institute of Agricultural Engineering

Via Celoria, 2 – 20133 Milan, ITALY.

Tel 0039 0250316857, Fax 0039 0250316845, loredana.dioguardi@unimi.it

Abstract

According to the laws in force the main requirements concerning food factories deal with their hygienic condition, safety and welfare for the workers, environmental protection from contaminants and processing functionality.

This paper points out the interaction between building solutions - such as their design, layout and materials - and environmental quality and aims to find crucial points related to hygiene and safety under working conditions. In particular, it analyses the interior materials mostly used for food processing, together with ripening premises. It examines the capacity of the materials to stand chemical and physical corrosion/aggression as well as the cleanliness of the premises, that is their suitability and compliance with legislation regarding safety in a working environment.

Through the analysis of several dairies, the major problems concerning hygiene were found to be connected with their incorrect layout, which is unsuitable for food processing, with the materials used, as well as with their design fostering filth. In fact, missing sealants between tile joints promote microbial development by accumulation of organic stuff similarly to what happens inside insufficiently ventilated premises. Moreover, old dairies show not washable walls, scraped plaster especially in poorly ventilated areas behind the vat and concrete floors highly deteriorated by lactic acid deriving from prolonged spilling of acid whey.

All problems are mostly due to inadequate knowledge by designers of the details concerning food processing, the necessary equipment and the conditions required by the process itself. Eventually, several buildings did not result to be safe, functional and convertible as they were not specifically designed for food processing.

Keywords: building structure, layout, finishing materials, environmental condition.

Introduction

Processing food means primarily protecting consumers by manufacturing safe food. Food safety requires integrated strategies for the whole supply chain including: sense of responsibility from workers, conditions steadily fit for conservation and eligible quality related to the environment and the structures of the buildings where products are made.

Several reasons can affect both structural and environmental conditions of food processing businesses:

- frequently they are housed in buildings not specifically designed for that purpose, so they lack safety, functionality and convertibility;
- being small businesses, their financial resources may not be enough to conform their buildings with regulations; in case they do, contradictory results can derive from the resources being low;
- improvements are usually due to sanctions to be avoided rather than to the businesses themselves to be ranked;

- they are designed without proper knowledge of the details concerning food processing, the necessary equipment and the conditions required by the process itself.

On account of what stated above and of the information gathered, this paper aims to make suggestions for a proper and functional design concerning small dairy facilities.

Material and methods

A survey was carried out in small dairies situated in mountain areas, usually close to their breeding farm; they process milk using craft methods to make cheese from local tradition. The businesses are situated in the valley floor (9 dairies) or on mountain pasture (9 huts) located in Valsesia, Valcamonica, Altopiano di Asiago and Monte Grappa

Our aim consisted in the examination of building and environmental quality of the dairies as well as their functionality related to both their specific production and business management. First, we checked for the basic building requirements consistent with EC regulation n. 852, 2004.04.29 (attachment II), even in the consideration of structural exceptions allowed to traditional productions.

Therefore information were gathered about the building structure, such as its layout, building typology, peculiarities of its architectural parts, finish materials, state of repair and cleanliness of the premises; about production, that is dairy processing, its flowchart, environmental conditions deriving from processing and required by the different production phases, its technology, its productive capacity and so on; about the management of the productive activities, e.g. method, timing and labour employed for cattle breeding and treatment, milking, cheese-making and dairy product selling.

Specifically, the following aspects were considered while examining the building structure:

1. protection of its interior from outside contamination or aerial contamination spread inside areas with different hygienic standards, through measuring air microbial charge;
2. cleanliness and preservation of the premises in respect to their specific processing, such as skimming, cheese-making and ripening.

As to aspect 1, protection from contamination of areas devoted to processing and reduction of transmission of aerial contamination, were examined the following aspects:

- level of care and state of repair of areas external to the dairy;
- existence of flooring between cattle-shed /dairy and around the buildings;
- layout, i.e. location and distance of the cattle-shed from the dairy, entrance to the buildings, arrangement of the processing premises, plants and equipment in relation to cheese-making flowchart;
- existence and integrity of systems due to stop infestation from outside, e.g. anti-insect nets, protective grids for openings, vents, drainage and so on;
- existence of structural parts favouring dust accumulation and dispersion.

Regarding aspect 2, were checked carefully adequate hygienic conditions and maintenance:

- internal finishes which should be easily cleaned, by measuring microbial contamination on their surface, and considering both how frequently and how they were cleaned;
- resilience and state of repair of such finishes considering their level of damage/deterioration;
- any hollow, crack, gap or any surface difficult to be reached;
- the dimension of the processing premises;
- possible presence of condensation or undesirable mould.

Results

External environment

In the mountains the external environment does not imply dangerous contaminating sources, as polluting industrial settlements are rare, and dairies are usually located within small urban contexts, such as the foot of a valley, or within isolated areas, such as alpine grazing.

No critical situations for hygiene due to external environment were found, except for one case because of a neglected massive vegetation as a possible source of weeds and waste leaning against the building.

Dairies within urban contexts showed external asphalt or concrete flooring and frequently an adequate slope to rainwater drainage. In some cases, soil subsidence was noted, which could provoke rainwater stagnation. In other cases, flooring only consisted of a layer of gravel, which anyway could avoid dust rising.

In an alpine environment, dairies are surrounded by pastureland. Where any flooring, was given, this might only consist of an area in front of the entrance to the dairy or of a one-or-two metre large concrete track around the building. To reduce contamination transmitted through air, the location of the cattle-shed as to the dairy, as well as its internal layout were considered very important.

Location of the premises

In the examined cases, the location of the cattle-shed as to the dairy showed the following typologies (Fig. 1):

- A: dairy and cattle-shed are sited in a single building;
- B: dairy and cattle-shed are sited in two different buildings with adjacent entrances;
- C: dairy and cattle-shed are sited within a distance of more than 50 metres.

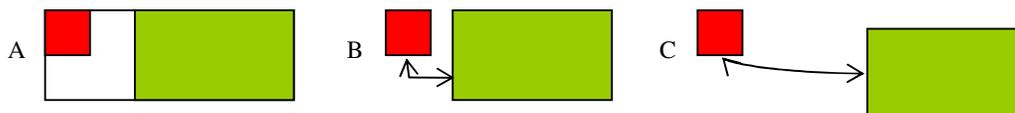


Figure 1. Location of cattle-shed (green) as to dairy (red)

The building typology of case A, when managed correctly, allows to keep distinct hygienic conditions of the two spaces. Air microbial charge measures showed it is possible to keep a difference of 10^3 - 10^4 magnitude in the microbial concentration between the cattle-shed and the dairy by simply closing the entry doors.

In case B contamination risk between cattle-shed and dairy is more frequent if doors and windows of both buildings overlook the same area and are kept open.

As to C, no microbial contamination through air is given when the cattle-shed is far enough from the dairy. Environmental contamination is present if between the cattle-shed and the dairy there is no flooring, not even consisting just of gravel or stones. In fact, the milker can dirty the premises of the dairy coming from the cattle-shed in muddy shoes. A water distributor external to the dairy can be useful.

Dairy Layout

According to the production process, dairies usually show from 2 to 4 premises. When the processing includes natural milk skimming, there is a room suitable for surfacing of fat globules; a necessary exclusive room to guarantee proper hygienic and environmental conditions of fresh temperature and ventilated ambience to the milk. In some dairies, natural milk skimming is performed in the same premises where milk is processed. In such a case, a correct organisation of the processing is due, so that no one is in the premise when milk settles.

Rooms for cheese-making and ripening are always given. A room for cheese dry salting can also be found. If cheese is brine salted, small tanks are normally set inside the ripening room. The ripening room must be fresh, ventilated and with no sudden change in temperature; that is why it is commonly a cellar under the ground. Ripening rooms in different building typology are also given; in such cases any possible contamination of cheese when carried outside must be avoided.

Internal layout of the premises might not allow the unidirectional progress of the processing flow, as it can occur in some dairies. Critical situations are due to an incidental use of processing premises. Dairies in the valley floor show more articulated layouts (U or L) consisting of premises specific to milk delivery and check; to churning; equipment cleaning; laboratory; staff changing room and facilities. Where performed, it is recommended to isolate equipment used for mechanic skimming and pasteurization inside a specific soundproof room to reduce staff's exposure to noise.

Protection from contamination sources of the internal environment

Systems against pest, such as grids for drainage or openings, were often not found. By passing through different rooms, pipes somehow created a connection among them; not every window installed anti-insect nets and the ones given were under a very bad hygienic and repair condition. A great deal of dust showed to be accumulated on beams, on internal windowsill and other flat surfaces, on hanging lamps and electric wires. To avoid filth, they should be as few as possible or at least inclined at an angle of 45°-60°, or again be covered with a round rake.

Adequate hygienic conditions and repairs in the processing premises

Good hygienic conditions, but moderate repairs for the processing premises checked. Damaged finishes, often decayed or even non existing on some surface areas. Different conditions depending on different resistance to mechanical and chemical stress of the materials used as internal finishes. The dimension of the space devoted to working operations seemed proper, even if cleaning the environment, the plants, and the equipment would be easier if they were placed at least one metre far from the walls.

Flooring

Red or glazed stoneware were the common flooring of the premises devoted to skimming and cheese-making, for older buildings and more recent ones respectively (Fig. 2/A). Washable, waterproof, chemical resistant, but with low resistance to mechanical stress if their thickness is not adequate. Moreover, red stoneware with a smooth surface is highly slippery especially in the presence of water and fat.

Concrete would not be suitable in such premises being scarcely hygienic and highly slippery, showing low resistance to acidity due to whey and lactic acid and dust when ageing. It is commonly used in the ripening rooms.

Flooring in synthetic resins are smooth and regular and having no tile joints they produce low noise even in the presence of trolleys carrying and moving the products. Ucrete would be the best synthetic resin for dairies among the products on the market, but it is not much used; it was found only in one dairy in the valley floor.

Glazed stoneware or red stoneware and concrete were usually found in the ripening rooms. Older buildings showed slabs of stone or gravel; wood boards on a concrete basis able to increase thermal conditions of the room was the flooring found in a hut. Ceramic materials were mainly noted, but they require the use of tiles well resistant to static and dynamic stress. A resistance due to proper thickness, dimension and geometrical shape of the tile itself. Clinker would be the best ceramic stuff for dairies, being hygienic, durable, chemically high resistant, almost waterproof, and 18-20 mm thick to offer adequate mechanical resistance. Only used in the largest dairies because of its cost. While fitting a floor, anti-acid products as sealants for tile joints should be used to avoid the bed deterioration, which anyway is not generally much considered. For the safety of the workers, flooring should be anti-slippery especially when washed; so tiles should undergo the following values:

- Friction coefficient $R=13$ (DIN 51130);
- Compression space $V=6-10$ (DIN 51130);
- Slippery resistance $\mu>0,50$ (B.C.R.A.).

Vertical finishes

The skimming and cheese-making premises generally resulted tiled or PVC wall-boarded. (Fig. 2/B). It is recommended to fit tiles for these walls having a determined thickness to make them resistant to strokes and knocks and to use metallic staff angles and boards to protect both angles and transit areas. Hygienically unacceptable are some mixed solutions where walls are tiled up to two metres and no finish is given above.

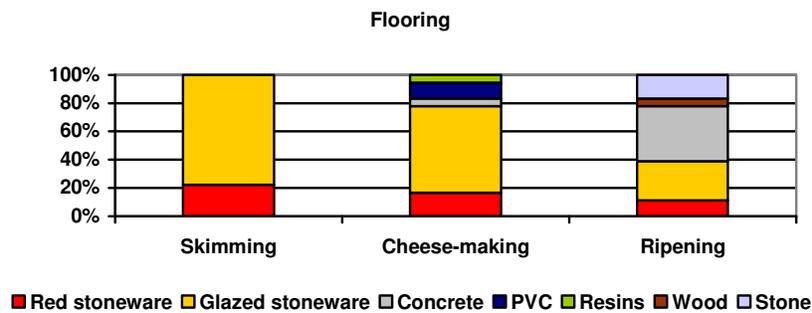
Paintings must be waterproof but breathable, to stand repeated washing and to avoid the peeling off of the finish. Paintings have no joints, but are less durable and need periodical renovation. Their resistance to environmental conditions must be carefully considered; in fact, they can rapidly decay in areas scarcely ventilated, such as behind a vat. High washable water-painting resistant to severe environmental conditions, such as high humidity and low ventilation, are nowadays marketed; inhibitors of micro-organisms, moulds and algae are also added. These paintings can be used on several finishes, even if its good and long durability can not be guaranteed on existing finishes. PVC wall boards are easily washable and show good resistance to mechanical and chemical stress; moreover they can be used to create defined spaces inside wide areas.

The ripening premises evidenced many and varied finishes, mainly raw concrete walls, but also plastered, tiled or PVC boarded. Environments with walls made in concrete are more subject to temperature range than where walls are made in bricks or stones.

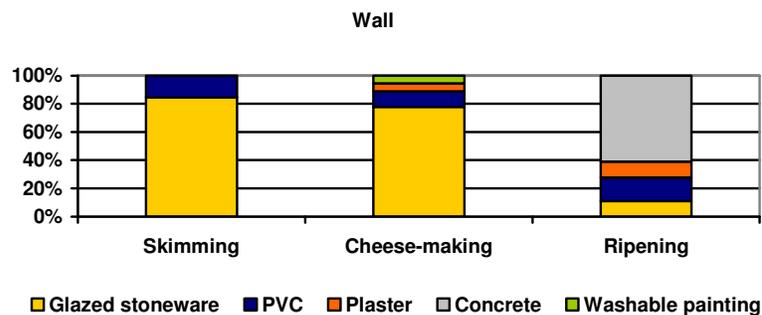
It is necessary to accurately prepare the bed with an intermediate layer of polyvinyl materials or epoxies to seal joints, cracks and hollows before plastering and laying the finish just to avoid filth accumulation and pests.

Ceilings

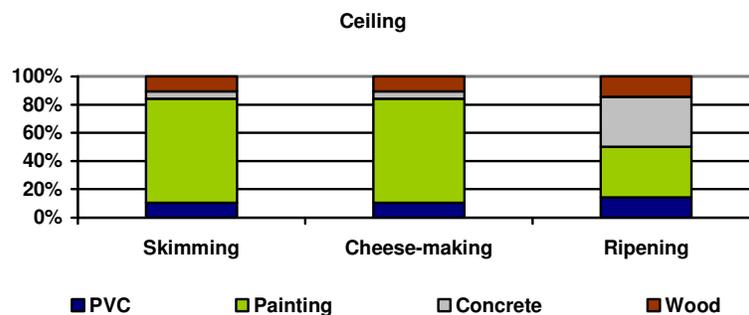
Ceilings (Fig. 2/C) were simply painted or made in PVC boards; in the ripening rooms they were in raw concrete. Huts showed wooden ceilings and also wooden building covering, a solution requiring more care and repairs. In fact, much mould was found in ceilings placed in low ventilated environment, which calls for periodical renovation of the painting.



A



B



C

Figure 2. Finishing materials used in dairies

Doors and windows

Doors and windows were wooden or made in metal. Insulated PVC doors were used for the air-conditioned ripening storerooms.

Wooden doors and windows need frequent cleaning and good repairs being porous and moisture sensitive. The bacterial charge measured on their surfaces demonstrated that when regularly brushed figures concerning wood are low, only few CFU/cm² similarly to tiles. Window glass is responsible of high condensation, particularly in winter. Therefore it is important to install glass apt to better thermal performance of the windows; e.g., low emission glass covered with metallic oxide can decrease heat loss and neutralize condensation, or high thickness glass, double-glazing and layered glass covered with viscoelastic material can also

be sound-proofing. Self-cleaning glass can be adopted where the windows are not easily accessible. Self-cleaning is due to a photo-catalytic and hydrophilic material which UV beams activate to decompose organic filth and make the surface hydrophilic. Rain water then washes decomposed residues and mineral dust. Sunlight in the processing premises can be reduced by installing windows including shutters in their double-glazing.

Doors and windows must be made in round, full or foamed structural shape. Windows in line with the wall are a good solution to avoid details which can be used as hygienically critical bases.

Conclusions

Traditional cheese productions are evolving as to their peculiarities because on account of different reasons their production environment is changing. Better hygiene of the processing premises requires the use of washable finishes, often incompatible with traditional stones and wood.

Processing premises in alpine grazing consist of small buildings, not always showing a good standard of repairs that could guarantee optimal hygienic conditions for cheese-making. No doubt such premises must become consistent with the European regulations about hygiene and environment. Nonetheless, the usual balance between a habitat and its bacterial population must be preserved while increasing hygienic conditions.

Traditional materials should not be associated to an idea of a filthy context; in fact, they allow a perfect harmony between the natural alpine environment and its buildings which represent its strong peculiarity.

In the last years, substantial financial resources have been invested on the repairs and restoration of existing buildings as well as on new ones. Frequently, contradictory situations occurred during such restoration work. In fact, processing premises originally made in stones were covered with washable finishes, but in many cases poor availability of water was not taken into consideration. Tiles for the finishes revealed scarcely resistant to stress due to the presence and transport of equipment for cheese-making, which is taken to the hut only during grazing period. In some cases, repairs and restoration resulted absolutely formal.

Actually, washable finishes can not be the only element favouring adequate hygienic conditions. Contamination must be reduced by adopting a suitable hygienic procedure during cheese-making, for example washing hands, or other works in the cattle-shed; by avoiding that other tame animals or people be inside during production and that waste be stockpiled nearby the dairy. And even distribution has a strong impact on the hygienic aspect of production.

A suitable management of production would be enough to produce food absolutely safe for the consumers even inside traditional buildings, especially in the consideration that exceptions to this scope have already been given. Buildings must be adjusted respecting traditional products. Regulations about hygiene when interpreted, notwithstanding exceptions, can represent a risk for the premises built in traditional materials, even to become illegal. And not only have traditional materials a strong appeal for the tourists, but also they have represented the best environmental conditions to make particular cheese for a long time.

It is therefore important to underline these aspects in the aim to supply exact information, even supported by targeted experimentation, concerning how to handle necessary adjustments in accordance with regulations just having in mind the safeguard and promotion of both typical products and traditional buildings.

References

CRITT IAA IDF. 1992. L'usine agro-alimentaire. Guide de la conception et de réalisation. Editions RIA.

Guidelines for hygienic design and maintenance of dairy buildings and services. 1997. Bulletin n. 324. FIL-IDF.

Guidelines for the hygienic design, construction and layout of food processing factories. 2002. CCFRA.

Guidelines for the design and construction of floors for food production areas. 2002. CCFRA Second edition.

Guidelines for the design and construction of walls, ceilings and services for food production areas. 2003. CCFRA Second edition.

Hall H.S., Rosén Y. 1963. Milk plant layout. FAO Agricultural Studies n. 59.

Hayes P.R. 1985. Factory Design and Construction in Food microbiology and hygiene. ELSEVIER APPLIED SCIENCE PUBLISHERS

Lopez-Gómez A., Barbosa-Cánovas G. 2005. Food plant design. TAYLOR & FRANCIS GROUP, CRC PRESS

Mariani F. 1991. Fonti e veicolazione della biocontaminazione nell'industria alimentare. Industrie alimentari, 9, 724-726.

Evaluation of dermal exposure to pesticides in greenhouse workers

Cerruto E., Emma G., Mallia I., Manetto G.

*Dipartimento di Ingegneria Agraria (DIA), Via S. Sofia 100, 95123 Catania,
Tel. +39 0957147514, Fax +39 0957147600, Italy, ecerruto@unict.it*

Abstract

According to a survey carried out at the Department of Agricultural Engineering of the Catania University, farmers in the province of Ragusa realise greenhouse plant protection by means of 15-20 spray applications, delivering volume rates ranging from 900 up to 1800 L/ha, according to the plants growth. The most widespread machineries are handheld high pressure spray lances, which expose the operators to high risks of dermal contamination.

This paper reports the results of some trials aimed at measuring the dermal exposure of operators during spray applications to tomato plants full developed. Experimental tests were carried out comparing two handheld spray lances, two working pressures (1 and 2 MPa), and two walking directions (forward and backwards). The spray lances were a "Yamaha C-6" lance with two nozzles, each with two orifices, and a high pressure spray lance with one 1.5 mm diameter turbulence nozzle.

The results showed as the dermal operator exposure could be greatly reduced performing spray applications walking backwards: with a reference volume rate of 1000 L/ha, the operator contamination was in fact 223 mL/h walking forward and 26 mL/h walking backwards. Moreover, when he walked forward, the greatest unitary depositions were on the right hand (0.550 $\mu\text{L}/\text{cm}^2$), the right foot (0.389 $\mu\text{L}/\text{cm}^2$), and the right arm (0.352 $\mu\text{L}/\text{cm}^2$), while when he walked backwards, they were on the feet (right = 0.080 $\mu\text{L}/\text{cm}^2$ and left = 0.075 $\mu\text{L}/\text{cm}^2$).

Fixing the operator movement (backwards), pressure and type of sprayer didn't affect exposure: it was on average 40 mL/h, mainly located on upper limbs (51.5%).

Keywords: spray lances, pressure, tomato.

Introduction

According to the Italian Central Statistics Institute (ISTAT, 2006), horticultural protected crops in Sicily account for some 8800 ha and 430660 t, mainly located in the province of Ragusa (4750 ha and 272650 t). Greenhouses, however, given the peculiar structural and climatic conditions (confined space, high temperature and relative humidity), are very specific agro-ecosystems with respect the open field. To ensure high productions, massive energetic and chemical (fertilizers and pesticides) inputs are necessary.

The risks in using pesticides are related to two main factors: intrinsic toxicity and level of exposure and absorption by organisms through the several apertures (dermal, inhalant, and ingestive). This is true not only for workers directly exposed, but also for consumers and common people, even if the absorption apertures can be quite different.

The risk of exposure for workers is present not only during pesticide applications, but also during mixture preparation, post-treatment operations, and activities connected to re-entry in greenhouses, such as harvesting (Aprea *et al.*, 2002). A recent survey carried out in Italy (Cerruto *et al.*, 2007) on about 200 horticultural and ornamental farms, revealed that each crop requires an average of 15 treatments, that the most common machineries are lances

and spray guns (71%), and that the use of personal protective equipment (PPE) isn't widespread, especially in preparing mixtures, when concentrated products are to be manipulated. Similar results emerged from surveys carried out in Turkey (Ergonen *et al.*, 2005) and Spain (Sánchez-Hermosilla *et al.*, 1998): handling of chemical products is done without taking all precautions to prevent exposures (inadequate use of PPEs) and there is a marked unawareness about their danger and toxicity.

The risks of exposure increase when pesticide applications are made by means of handheld equipments, as increase the possibilities of a direct contact with the mixture (Bjugstad and Torgrimsen, 1996). Restricting studies to dermal exposure, the amount of mixture collected by the operator body is related to several factors: crop, spraying equipment, operator movement, environmental conditions. Some of them are investigated in this paper, which reports some of the results of a research developed within the 2005 National Relevant Interest Project (PRIN) "Machinery and their adjustment for a sustainable pest control in glasshouses". Namely, it reports the results of some operator exposure trials, measuring his contamination during spray applications to tomato plants full developed by means of handheld high pressure spray lances, comparing operator movement, type of spray lance, and working pressure.

Materials and methods

Planning of the experimental tests

The paper reports the results of a research activity developed in two steps. Firstly, the operator exposure was measured, comparing forward and backwards movement and using a handheld spray lance at fixed pressure (Trial 1). Secondly, on the basis of the results obtained, the experiment was repeated, varying pressure and type of spray lance (Trial 2).

In both experiments, spray applications were performed on tomato plants fully developed.

Plants features

Experimental trials were carried out in two greenhouses located in the territory of Ragusa, area where greenhouse crops are very widespread. The plant protection is usually accomplished by means of 15-20 spray applications per year, delivering, mainly by means of high pressure handheld spray lances, volume rates ranging between 900 up to 1800 L/ha, according to the plants development.

The crop, cv *Ikram*, was arranged in twin rows, with the main characteristics reported in Table 1. As a significant part of the operator contamination is due to its contact against the sprayed plants, their main geometrical features were measured (Table 2).

Table 1. Main crops features.

Trial	Distance between rows, m	Distance between twin rows, m	Row spacing, m	Plant density, ha ⁻¹
1	0.55	1.25	0.35	31 700
2	0.60	1.40	0.35	28 600

Table 2. Main geometrical features of the sprayed area on the plants.⁽¹⁾

Trial 1						
	Minimum height	Maximum height	Thickness at 0.60 m	Thickness at 1.00 m	Thickness at 1.40 m	Thickness at 1.80 m
Mean, m	0.49	1.98	0.46	0.48	0.45	0.36
CV, %	27	3	27	15	19	34
Trial 2						
	Minimum height	Maximum height	Thickness at 0.95 m	Thickness at 1.50 m	Thickness at 1.95 m	
Mean, m	0.83	2.45	0.45	0.58	0.63	
CV, %	26	8	33	30	28	

(1) Average of 12 measures.

Experimental tests

The first experimental trial was carried out using the most widespread equipment, that is a handheld spray lance "Yamaha C-6" with two steel nozzles, each with two orifices (Figure 1). The selected working pressure was 2 MPa, that usually adopted by farmers. The flow rate at the nozzles was that reported in Table 3. Spray applications were performed walking forward (the commonest manner) and backwards. For each modality, three replicates were made, each consisting in a 60 m path (outward and return) between two twin rows. Measuring the walking speed and knowing the flow rate at the nozzles, the volume application rates were also calculated (Table 3).

Given the results of the first trial, the experiment was repeated in a similar manner, fixing the operator movement (backwards) and comparing two pressures (1 and 2 MPa) and two spray lances (the Yamaha-C6 and a "conventional" one with one turbulence nozzle, 1.5 mm diameter, Figure 2). The effective pressure values were checked by means a pressure gauge installed near the helve.

A full factorial experiment was designed, with two pressures, two spray lances, and three replicates, arranged according to a randomised complete block design (Table 3). The greater walking speed (0.8 m/s vs. 0.5) was due to the different features of the plants (lower size of the vegetation to be sprayed).

Table 3. Experimental plan.

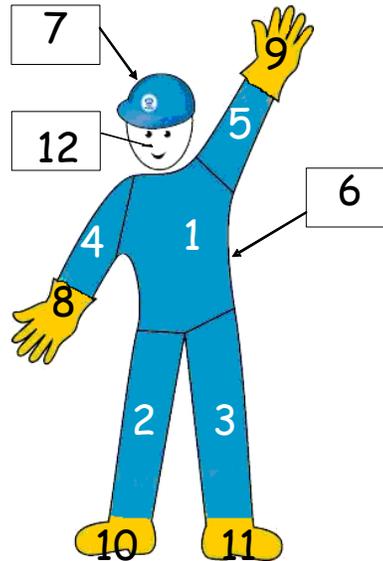
Trial 1						
Movement	Spray lance	Pressure, MPa	Speed, m/s	Flow rate, L/s	Volume rate, L/ha	
forward	Yamaha-C6	2	0.6	0.08	1423	
backwards	Yamaha-C6	2	0.5	0.08	1649	
Trial 2						
backwards	Yamaha-C6	1	0.8	0.06	698	
backwards	Yamaha-C6	2	0.8	0.08	1010	
backwards	Conventional	1	0.8	0.07	801	
backwards	Conventional	2	0.8	0.09	1127	



Figure 1. Handheld Yamaha-C6 spray lance. Figure 2. Conventional spray lance.

Spray applications were performed delivering a water solution with 2% of food dye Red Ponceau used as a tracer. The operator was wearing a polypropylene disposable overall, completed with cover shoes, respirator, and latex gloves (Figure 3). After each replicate, the overall was cut in several pieces as depicted in Figure 4, and the contamination of each piece was measured in laboratory by means of a spectrophotometric technique. It was expressed in microlitres per square centimetre and in millilitres per working hour. To account for the differences in the spray volume rates, values were normalised to the common volume rate of 1000 L/ha.

Data was statistically analysed, separately for each trial. All computations and graphical representations were performed by means of the open source software R.



- 1: chest
- 2: right leg
- 3: left leg
- 4: right arm
- 5: left arm
- 6: back
- 7: head
- 8: right hand
- 9: left hand
- 10: right foot
- 11: left foot
- 12: respirator

Figure 3. Overall to measure the operator exposure. Figure 4. Scheme to measure the operator exposure.

Results

The Trial 1 results showed that, delivering 1000 L/ha, the operator contamination was 223 mL/h walking forward and 26 mL/h walking backwards. The ratio was 8.6:1, but for some body parties (chest, left arm, left hand, left leg), it was greater than 10:1. The greater contamination walking forward is mainly due to the operator contact with the sprayed plants, but also to the fact that he partly hit the sprayed cloud with his one's body.

Looking at the data more in depth (Figure 5), one can observe that, walking forward, the operator right side (arm, leg, hand, and foot) was ever more exposed than the left one, while the opposite happened walking backwards. This because the operator scraped his body against the sprayed plants: when he walked forward, he scraped its right side against a sprayed row during both outwards and return path, and its left side against a sprayed row only during the return path. When he walked backwards, he scraped only its left side against a sprayed row only during the return path. In both cases, legs were the body parts that accounted for the greatest contamination (Figure 6): 40% walking forward and 48% walking backwards. This because the foliage to be sprayed was starting from almost the ground (Table 2), so the operator, oscillating the spray lance, inevitably was directing the spray jet against his lower limbs.

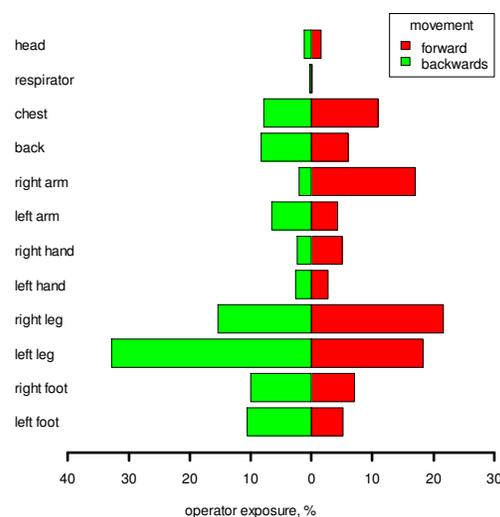
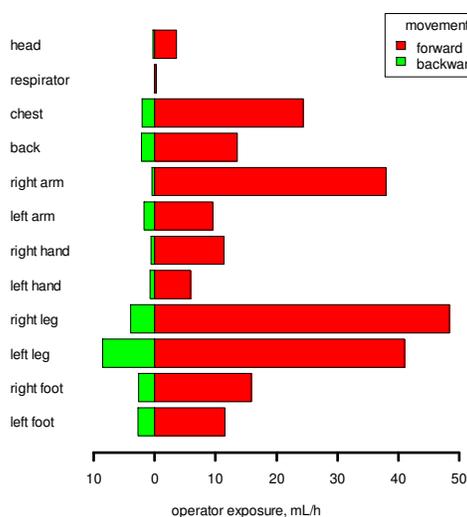


Figure 5. Trial 1: operator exposure per working hour.

Figure 6. Trial 1: percentage exposure subdivision among the body parts.

Walking forward, the greatest unitary deposition (Table 4) was on the right hand ($0.550 \mu\text{L}/\text{cm}^2$), followed by the right foot ($0.389 \mu\text{L}/\text{cm}^2$), and by the right arm ($0.352 \mu\text{L}/\text{cm}^2$), while walking backwards, the greatest values were on feet (0.080 and $0.075 \mu\text{L}/\text{cm}^2$, left and right respectively).

As these results demonstrated that the operator exposure during spray applications could be greatly reduced walking backwards, subsequent Trial 2 experimental tests were designed accordingly.

The analysis of variance showed as neither pressure nor type of spray lance influenced significantly the overall contamination of the operator (Figure 7). On average, delivering 1000 L/ha, the operator collected on his body 40 mL/h of mixture. This value is comparable with

26 mL/h, measured in similar conditions in the previous experiment. The reduction in the exposure measured with the Yamaha-C6 spray lance at the pressure of 2 MPa (14 mL/h) was not statistically significant.

Table 4. Trial 1: unitary deposition ($\mu\text{L}/\text{cm}^2$) on the body parts.

body part	forward	backwards	ratio	body part	forward	backwards	ratio
head	0.053	0.005	9.99	right hand	0.550	0.035	15.68
respirator	0.030	0.018	1.65	left hand	0.299	0.040	7.48
chest	0.094	0.009	10.16	right leg	0.252	0.025	10.26
back	0.053	0.010	5.33	left leg	0.214	0.054	3.94
right arm	0.352	0.006	59.02	right foot	0.389	0.075	5.17
left arm	0.091	0.019	4.68	left foot	0.281	0.080	3.53

Figure 8 shows the percentage subdivision of the mixture collected by the operator among his body parts. It shows the great exposure of the left arm, that alone accounted for 39% of the overall contamination. This result is in agreement with the spray applications carried out walking backwards. As a whole, hands and arms accounted for 51.5% of the total exposure, head and trunk for 24.1%, and legs and feet for 24.4%. The greater exposure of the upper limbs with respect the previous results, must be related to the different plants features (Table 2): as the foliage to be sprayed was starting from about 0.8 m, the operator was directing the spray jet preferably upwards.

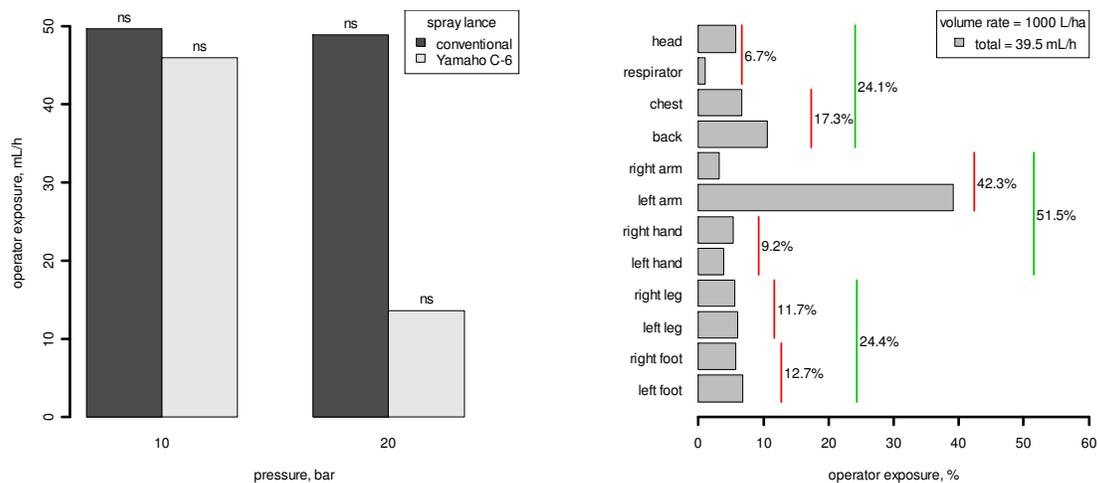


Figure 7. Trial 2: operator exposure vs. pressure and spray lance type (ns: subdivision among the body parts, differences not statistically significant).

The weighted unitary deposition (Figure 9) ranged from 0.008 $\mu\text{L}/\text{cm}^2$ to 0.031 $\mu\text{L}/\text{cm}^2$,

with a mean value of $0.024 \mu\text{L}/\text{cm}^2$. The most contaminated body part was the left arm ($0.116 \mu\text{L}/\text{cm}^2$, Figure 10) due to its scraping against the sprayed plants, followed by the right hand ($0.082 \mu\text{L}/\text{cm}^2$), that was holding the spray lances.

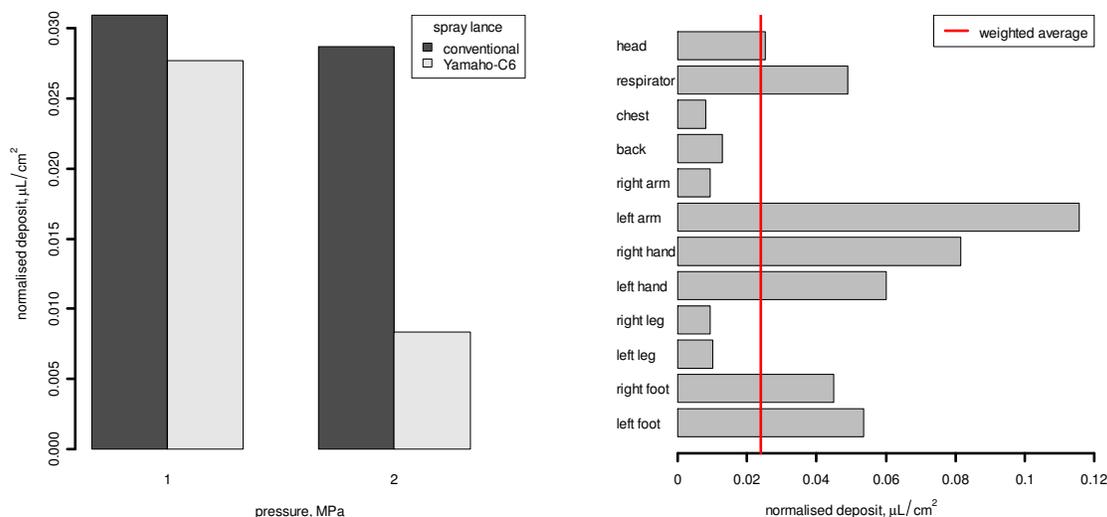


Figure 9. Trial 2: normalised deposit on the operator vs. pressure and type of spray lance. Figure 10. Trial 2: average normalised deposit on the body parties of the operator.

Conclusions

Greenhouse crops usually require a high number of spray applications, with volume rates often greater than 1000 L/ha. The most widespread spray machineries are handheld high pressure spray lances, which expose operators to high risks of contamination. Furthermore, operators show little regard for safety aspects, not properly wearing adequate personal protective equipment.

So in this piece of research the measurement of the volume of mixture collected by the operator body during the treatment of full developed tomato plants was investigated. Comparing two pressures (1 and 2 MPa), two types of spray lance (with one and two nozzles), and two types of operator movement (forward and backwards), the results showed as the main factor in reducing the exposure is the operator movement: with a reference volume rate of 1000 L/ha, the operators collected on his body 223 mL/h of mixture walking forward and 26 mL/h walking backwards. As the working capacity is only little reduced (Table 3), carry out spray applications walking backwards should be preferred for safety reasons.

The body parts more exposed were related to the plants features: when the foliage to be sprayed started from almost the ground, the highest contamination was found on the lower limbs, while when the foliage started from about 0.8 m, the highest contamination was found on the upper limbs. These results should convince operators of wear proper PPEs in any circumstance, so to safeguard their own safety.

References

Aprèa C., Centi L., Lunghini L., Banchi B., Forti M.A., Sciarra G. 2002. Evaluation of respiratory and cutaneous doses of chlorothalonil during re-entry in greenhouses. *Journal of Chromatography B*, 778 (2002) 131-145

Bjugstad N., Torgrimsen T. 1996. Operator safety and plant deposits when using pesticides in greenhouses. *J. Agric. Engng Res.* (1996) 65, 205-212.

Cerruto E., Balsari P., Oggero G., Friso D., Guarella A., Raffaelli M. 2007. Operator Safety during Pesticide Application in Greenhouses: a Survey on Italian Situation. *GreenSys 2007*, Naples, in press.

Ergonen A.T., Salacin S., Hakan Ozdemir M. 2005. Pesticide use among greenhouse workers in Turkey. *Journal of Clinical Forensic Medicine* 12 (2005) 205-208.

ISTAT. 2006. www.istat.it.

R Development Core Team. 2007. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0, URL <http://www.R-project.org>.

Sánchez-Hermosilla J., Pérez R., Díaz M. 1998. Study of labour risks due to the application of phytosanitary products protected crops. *Ageng 98*, Oslo, paper no. 98-G-033.

Experimental trials to evaluate risks from noise and particulate matter in a pasta factory

Bianchi B.¹, Cassano F.², Mongelli C.³

¹PRO.GE.S.A. dept., University of Bari – via Amendola 165/a, 70125, Bari (Italy) -, Tel. + 39 080 5443096 - Fax + 39 080 5443080, biagio.bianchi@agr.uniba.it.

²Department of Internal and Public Health, Policlinico di Bari - piazza G.Cesare - 70124 Bari, Italy, Tel/fax +39 080 5478217, f.cassano@medlav.uniba.it

³PRO.GE.S.A. dept., University of Bari – via Amendola 165/a, 70125, Bari (Italy) -, Tel. + 39 080 5443096 - Fax + 39 080 5443080, carlo.mongelli@agr.uniba.it

Abstract

The trials were carried out in a pasta factory in Bari Province and confirmed that the existent studies regarding health risks in the pasta production sector can be used as the starting point. However it is necessary to make a specific analysis of the parameters which constitute risk factors, using scientific apparatus.

Evaluation of the risks deriving from noise involved a problem of interpretation. The differences found between data obtained with a phonometer and data obtained with a dosimeter may be in contrast, and the dosimeter data can be a source of concern for the workers' health and therefore for their employers who are responsible for health and safety. In actual fact, when the reality of the situation was examined, it was seen that different plant operations involve workers' movements which can stress the microphones differently from acoustic pressure. Therefore, the noise levels which are actually indicative of the situation in the workplace are the phonometer data. However, these too were quite high: daily exposure levels of over 80 dB(A), 85 dB(A) and 90 dB(A) in one case, while the impulsive noise levels were always lower Lpk=112 dB(C).

Evaluation of the risk from exposure to particulate matter showed concentrations of inhalable particulate matter PM 10 which were constantly below the level of TLV-TWA = 0.5 mg/m³ adopted by the ACGIH as the maximum inhalable dose in eight hours of work. This shows the efficiency of the dust extractor system, which the firm recently upgraded.

However, we looked at preventive measures which consisted of:

- working regulation defined by applying industrial health and safety procedures ;
- correct and continuous maintenance of the extractor system;
- identification of workers who are more susceptible to respiratory diseases – mostly caused by semolinas powder - even when exposed to levels below TLW.

This study has further confirmed that the risk evaluation is not an *exact science*; in that it does not consist only of technical and mechanical factors, but needs also to consider the many factors connected to workers' interaction with the workplace.

Keywords: phonometer and dosimeter measures, semolinas powders, TLV-TWA levels, safety procedures.

Introduction

Pasta factories are highly mechanised, particularly at the stages of production when the pasta is extruded, dried and packaged (Matteucci D., Rabazzi S. 2007). This means that the machinery used is increasingly efficient, but can create dust and noise pollution (Cappelli M., Coscia M. 2005). The development of mechanised systems for the production cycle leads to changes in the lay-out of the workspace, in the types of work carried out by the workforce, and in the interaction between man and machine. Consequently the methodologies and the

tools used to evaluate risks in the workplace also change, because they depend on the health problems and accidents which can happen during the production process, and also on the limits imposed by the technical regulations – which often translate into legal obligations (Benvenuti F. et al. 1998).

When it comes to dust, some authors have highlighted cases of conjunctivitis in factories using products similar to semolina flour (Ames R.G. 1991) which need further study in order to better define the correlation between cause and effect. The dangers of prolonged inhalation of flour dust in terms of chronic respiratory disease are little known, unlike the results of some scientific studies on other agri-food products (Becklake M. et al. 1997; Cassano F. et al. 2000; Jayawardana P. and Udupihille M. 1996; Zock J.P. et al. 1995).

Noise pollution is caused by the highly mechanised plants installed in the last few years, and risk assessment is correlated not only to the kind of machinery used, but also to other factors like the degree of maintenance, the positioning of machinery in the buildings, the structure of the buildings etc. (Di Candia E., Mongelli C. 1996; Cascone G. et al. 1996). Such problems are often experienced in the agricultural and agro-industrial sector, particularly during the sorting and packing phases (Merseburger A. 1996).

Considering the economic importance of this sector, and the problems concerning working conditions, the objective of this study was to evaluate risks from dust and noise in an Apulian pasta factory in a country area of the Province of Bari, also in relation to the limits set by the current legislation and the technical regulations (ACGIH, 2006; D.Lvo n. 81/2008).

Table 1. Main technical characteristics of the studied factory.

Company name	Location	Products	Working capacity	Personnel organization
Riscossa Pasta factory F.lli Mastromauro S.p.A	Corato (BA) – Apulia - Italy	– Dry pasta: pasta factory – Matasse – egg pasta: pasta factory – Rice: associate factories – Peeled tomatoes: associate factories – Pureed tomatoes: associate factories – Flour and semolinas: associate factories	– Long pasta line: 3500 kg/h – Long pasta line: 2000 kg/h – Short pasta line: 3500 kg/h – Short pasta line: 2200 kg/h – Short pasta line: 1200 kg/h – Matasse line: 400 kg/h – Matasse line: 700 kg/h – Special shapes line: 400 kg/h	– n. 13 clerical workers; – n. 80 workers; – n. 3 managers; – n. 1 chairman.

Materials and methods

The experimental trials were carried out in the pasta factory Riscossa in Corato (BA - Italy) which produces short and long pasta, matasse, egg-pasta and special shapes. Production is concentrated on short and long pasta lines which have working capacity of 35 q/h and about 20 q/h (table 1), and are situated near the outside walls of the building (figure 1).

In order to evaluate the risks of exposure to noise and dust inhalation, we examined the production cycle and its layout. Then we identified the *critical areas* for these risk factors, based on dust and noise generated, and on the movements of the factory personnel.

In fact, production takes place in a single working area (figure 1) where the pasta is prepared and extruded, dried and packaged. The workforce (n. 80 workers) is concentrated in the area of the presses and in the storage/packaging area, because the drying stage is completely automated and only requires workers to be present occasionally in order to carry out checks. For this reason, the equipment for measuring noise and dust was placed in n. 6 representative positions:

- presses area for the short pasta line (sample point 1 in figure 1);

- presses area for the long pasta line (sample point 2 in figure 1);
- area between the dryers and the storage area for the short pasta line (sample point 3 in figure 1);
- area between the dryers and the storage area for the long pasta line (sample point 4 in figure 1);
- short pasta packaging area (sample point 5 in figure 1);
- long pasta packaging area (sample point 6 in figure 1).

Evaluation of noise risk

Evaluation of the risk from exposure to noise was carried out in accordance with Italian laws (D.Lvo n. 81/2008) which correspond to EC Directive 2003/10/CE.

We measured weighted and instant noise levels, using: Quest phonometers integrators/dosimeters, Noise pro DLX-1 Model; Phonometer VI 400 Pro 8248; corresponding to the following standards:

- ANSI S1.25 – 1991, ANSI S1.4 – 1983: Class/Type 2, Class/Type 1;
- IEC 651 – 1979: Class/Type 2, Class/Type 1;
- IEC 804 – 1985: Class/Type 2, Class/Type 1;
- IEC 1252 – 1993;
- IEC 61672-1, Class/Type 1.

We determined the Continuous Equivalent Level (L_{eq}) in order to reduce the effect of phonometric fluctuations. This represents the level of a hypothetical constant noise, with the same duration and equivalent energy level, as the variable noise measured; it is the average total noise. The environmental noise measurements were weighted according to Curve A, which is closest to the sensitivity of the human ear to the different frequencies, while impulsive noise measurements were weighted according to Curve C.

According to international regulations ISO 1999: 1990, partially acknowledged by Italian law, the level of daily exposure to noise is expressed by the formula:

$$L_{EX,d} = LAeq, \tau_e 10 \log \frac{\tau_e}{\tau_0} \quad (1);$$

where:

$$LAeq, \tau_e = 10 \log \left[\frac{1}{\tau_e} \int_0^{\tau_e} \left(\frac{p_A(t)}{p_0} \right)^2 dt \right] \quad (2);$$

with:

τ_e = daily duration of personal exposure of a worker to noise, including the daily share of over-time work;

$\tau_0 = 8 \text{ h} = 28.800 \text{ s}$;

$p_0 = 20 \text{ } \mu\text{Pa}$;

p_A = instant acoustic pressure weighted in Scale A.

The average daily level of exposure per task was calculated according to the levels obtained for every work place using the following ratio:

$$L_{EX,8h} = 10 \log \sum 10^{0.1 L_{EX,d}} \quad (3)$$

Numerical processing of the data was carried out using periodically up-dated Quest software, mod. QuestSuite professional, rev. 1.70 e QuestSuite professional II.

Before and after each series of measures, the instruments were calibrated using a calibrator Quest mod QC 10/20, corresponding to the following standards:

- ANSI Standard for Sound Calibrators S1.40-1984;
- IEC 942-1988 for Sound Calibrators.

A phonometer was installed in each sample point for 8 hours and for shorter periods, which results represent the working day: 120 min, 47 min. All phonometers were adjusted in accordance with the legal requirements (D.Lvo n. 81/2008) before noise levels were measured.

In order to take personal noise measurements, dosimeters were worn by:

- n. 3 factory workers and n. 1 wiring maintenance technician, mostly at work near the presses and occasionally at the dryer;
- n. 4 factory workers mostly at work in the packaging area and occasionally at work in the storage area and at the final part of the dryer.

These tests were also repeated, with workers wearing the dosimeter for 8 h and shorter periods of time which results represent the working day: 38 min, 39 min, 40 min, 46 min, 47 min, 52 min, 57 min; in these last cases it was also necessary to determine the level of $L_{EX,8h}$, according to (1) and the (3) because these workers worked on the line for 4-6 hours, and then worked in quieter areas ($LA_{eq, \tau_e} = 70$ dB(A)) for the rest of the time.

Evaluation of dust risk

When we talk about "atmospheric dust" we intend a mixture of solid and liquid particles suspended in the air. These vary in dimension, composition and origin, according to how they were formed. Some of the particles which make up atmospheric dust are emitted by natural and man-made sources (primary particles); others derive from a series of chemical and physical reactions which take place in the atmosphere (secondary particles). Total suspended dusts (*PTS*) consist of a very heterogeneous set of solid and liquid particles which are small enough to remain suspended in the air.

Dusts are classified according to the diameter of the particles and their concentration in the air is expressed in $\mu\text{g}/\text{m}^3$. The diameter of particles can vary from a minimum of 0,005 μm to a maximum of 100 μm . Within this range, particles are defined as:

- coarse, with diameter included between 2,5 and 30 μm ;
- fine, with diameter lower than 2,5 μm .

The smaller of the dust particles, have greater capacity to penetrate into the lungs and to cause health problems. This is why Italian laws about air pollution regulate the presence of particles *PM* (particulate matter) *10* with diameter lower than 10 μm in the air, including a sub-group of finer particles called *PM2,5* with diameter lower than 10 μm . Although these dusts have different chemical compositions and behave differently in the atmosphere, about 60% consists of the finest particles.

The *PM10* are more interesting in health terms than *PTS*. and are also called *inhalable dusts* because they can penetrate past the larynx. *PM2,5* are called *respirable dusts* because they are able to penetrate into the lower reaches of the respiratory system (from the trachea to the lung alveoli).

The levels of dust were measured in a fixed sample point, in order to evaluate the exposure of each worker to the most dangerous dusts, that is to say the *PM10*; a direct-read dust analyser measures how the dust particles inside its sample chamber refract the light emitted by a laser diode. The sampled air flow is crossed by a light with a wavelength of 780 nm. Refraction varies according to particle granulometry and the refractive index, and is proportional to the quantity of dust contained in the sample. In fact, the particles refract the light in all directions and it is then captured by a photometer at an angle of 90° to the laser beam and to the sample air flow. The light is then converted electronically into a number proportional to the concentration of dust. The proportional factor used by DustTrack is calculated with reference to the A1 Arizona american Test wich follows the standard legal calibration ISO 12103-1. The apparatus has a calibration certificate.

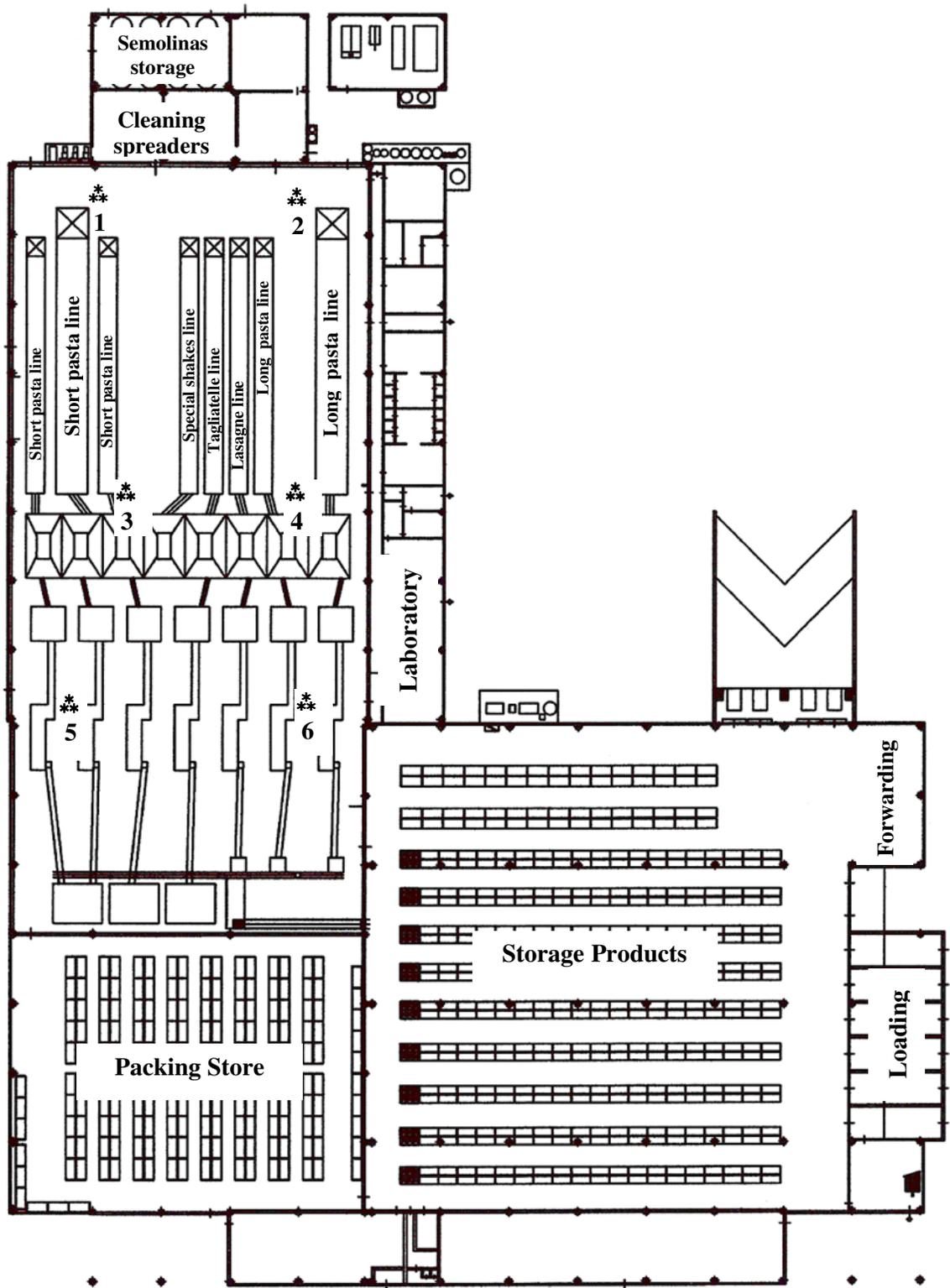


Figure 1. Schematic plan of the studied pasta factory; the symbols (⌘) indicate the noise and dust fixed sample points. Image is not drawn to scale.

Results

Evaluation of noise risk

The Italian laws and Reg. EC 2003/10 set the following limits:

Exposure limit levels: respectively $L_{EX,8h} = 87$ dB(A), $L_{EX,ppeak} = 140$ dB(C);

Upper levels of action: respectively $L_{EX,8h} = 85$ dB(A), $L_{EX,ppeak} = 137$ dB(C);

Lower levels of action: respectively $L_{EX,8h} = 80$ dB(A), $L_{EX,ppeak} = 112$ dB(C).

The measurements carried out in the fixed sample points (tables 2 – 3 - 4) showed that exposure times of less than 8 hours give levels very similar to those obtained for 8 working hours, although almost always lower. In fact, the machines do not stop during the working day, and the continuous noise produced is practically constant. However, the situation we studied was at the limit when it came to defining the employer's obligations:

1. warning signs and delimitation of danger zones (in excess of the Upper level of action);
2. use of individual protective equipment (in excess of the Lower level of action) and obligation to wear it (in excess of the Upper level of action);
3. interventions on machinery, production processes and task organisation (in excess of the Exposure level limit)
4. training and information (in excess of the Lower level of action);
5. health monitoring (in excess of the Upper level of action).

In this specific case, the level 87 dB(A) (Exposure level limit on 8h) is exceeded at the beginning of the short pasta line only when measurements are carried out with the phonometer on for 8h; for shorter exposure times, the L_{EX, τ_e} are mostly between the Upper level of action on 8h (85 dB(A)) and Lower level of action on 8h (80 dB(A)) (table 2). Similar levels to these were also measured in the other sites on short pasta line, in the storage area (table 3) and in the packaging area (table 4).

The difference between the levels measured for 8h and the levels measured for shorter times are much less evident on the long pasta line. Here the maximum levels were always found in the press area, near to 80 dB(A); the levels of exposure measured at the other sites were always less than Lower level of action 8h (tables 3 - 4).

The impulse noise was generally lower than Lower level of action (112 dB(C)), and only the press area is subject to impulsive noises of 120 dB(C) (tables 2-3-4), which therefore do not reach the Upper level of action (137 dB(C)); high levels of impulsive noise were measured in this area for all exposure times (table 2). At the other sites where measurements were made, high levels were found of $L_{EX,ppeak}$ for exposure times of less than 8 h (tables 2-3).

It is evident that in this type of working situation, the choice of the time period for measuring noise levels is of fundamental importance to obtain levels which once integrated onto the exposure time according to (2), then effectively correspond with the noise exposure during the entire working day; the choice of relatively short exposure times is frequent for professionals in this sector, but does not mean exclude the possibility of taking measurements over longer time periods if the levels are found to be near the limits.

The presses area is the noisiest area, because these machines are used for a great many operations (feeding, kneading, extrusion die and cutting) creating acoustic pressure which tends to add up; the noise of the short pasta line is accentuated by the "shaker pre-dryer" where the mechanical stress of the vibrating parts tends to increase the continuous component of the acoustic pressure. In the area where the dough is prepared and extruded, there is a greater discrepancy between the levels found for 8h and those obtained with shorter exposure times, especially for the short pasta (table 2); therefore the noise caused by the presses and the

pre-dryers is more variable than the noise created by the packaging machinery (tables 3 – 4), and requires longer times for measuring exposure levels.

For this reason, the very careful maintenance is necessary for the machinery in this part of the line, especially for the short pasta, so as to keep the noise levels under control, because these tend to exceed the Lower levels of action.

The impulsive component of environmental noise examined does not seem to be influenced by the time period used for measurement, nor by the continuous noise produced by the machines. High levels were measured for short periods of time which were not found at the same place for longer periods; in addition, high levels were found at the sites on the long pasta line in different places from the presses, where the highest levels of continuous noise are produced. These peak levels can be attributed to occasional factors connected with task organisation and machine maintenance.

For example, the movement of boxes, the vacuum pumps, the machines which recovery and grind scraps, the fans in the dryers are all stages in the production process where correct personnel and machines management can reduce the risks from impulsive noise. These machines can function discontinuously - and like many sources of impulse noise – do not have much influence if the system is sufficiently insulated. So it is important to check the apertures of the compartments containing this machinery, and make sure that lubrication and periodic cleaning are carried out, and that the machinery is correctly used, in order to prevent occasional cavitation.

Table 2. Values of equivalent (LAeq,Te) and impulsive (LEX,ppeak) noise levels measured in the noise sample points of the machines area: sample point 1 near short pasta line; sample point 2 near long pasta line (Figure 1).

Noise levels	Te = 8 h 1) short pasta	Te = 8 h 2) long pasta	Te = 2 h 1) short pasta	Te = 2 h 2) long pasta	Te = 47 min 1) short pasta	Te = 47 min 2) long pasta
LAeq,Te (dB(A))	90.1 = LEX,8h	81.9 = LEX,8h	85.5	82.5	84.7	81.9
LEX,ppeak (dB(C))	121.1	129.2	121.2	104.9	123.1	118.3

Table 3. Values of equivalent (LAeq,Te) and impulsive (LEX,ppeak) noise levels measured in the noise sample points between drier and silo: sample point 3 near short pasta line; sample point 4 near long pasta line (Figure 1).

Noise levels	Te = 8 h 3) short pasta	Te = 8 h 4) long pasta	Te = 2 h 3) short pasta	Te = 2 h 4) long pasta	Te = 47 min 3) short pasta	Te = 47 min 4) long pasta
LAeq,Te (dB(A))	83.5 = LEX,8h	77.2 = LEX,8h	81.9	77.5	80.2	76.8
LEX,ppeak (dB(C))	104.9	110.2	110.0	106.4	118.8	121.7

Table 4. Values of equivalent (LAeq,Te) and impulsive (LEX,ppeak) noise levels measured in the noise sample points of the packaging area: sample point 5 near short pasta line; sample point 6 near long pasta line (Figure 1).

Noise levels	Te = 8 h 5) short pasta	Te = 8 h 6) long pasta	Te = 2 h 5) short pasta	Te = 2 h 6) long pasta	Te = 47 min 5) short pasta	Te = 47 min 6) long pasta
LAeq,Te (dB(A))	83.2 = LEX,8h	76.0 = LEX,8h	82.2	75.8	80.5	77.2
LEX,ppeak (dB(C))	104.9	108.7	108.7	106.4	121.2	116.5

Dosimeter readings may be useful to check the levels of personal exposure to which workers are subjected. However, the dosimeter data (tables 5 – 6) far exceed the limits allowed and diverge noticeably from the data obtained from readings at fixed sites, and therefore must be interpreted correctly.

Table 5. Values of equivalent noise levels ($L_{Aeq,Te}$), daily noise levels ($L_{EX,8h}$) and impulsive noise levels ($L_{EX,ppeak}$) measured with personal dosimeters worn by four operators of the machines area (Figure 1).

OPERATOR	$L_{Aeq,8h} = L_{EX,8h}$ (dB(A))	$L_{EX,ppeak}$ (dB(C))	$L_{Aeq,Te}$ (dB(A))	$L_{EX,ppeak}$ (dB(C))	$L_{EX,8h}$ (dB(A))
1 Machine operator	92.0	132.2 ($T_e = 8$ h)	93.6 ($T_e=46$ min)	137.4 ($T_e=46$ min)	91.3
2 Machine operator	91.5	133.8 ($T_e = 8$ h)	92.8 ($T_e=47$ min)	138.2 ($T_e=47$ min)	90.8
3 Machine operator	94.1	128.9 ($T_e = 8$ h)	96.2 ($T_e=38$ min)	130.6 ($T_e=38$ min)	93.3
4 Electrician	93.4	138.3 ($T_e = 8$ h)	95.2 ($T_e=38$ min)	142.5 ($T_e=38$ min)	92.4

Table 6. Values of equivalent noise levels ($L_{Aeq,Te}$), daily noise levels ($L_{EX,8h}$) and impulsive noise levels ($L_{EX,ppeak}$) measured with personal dosimeters worn by four operators of the silage/packaging area (Figure 1).

OPERATOR	$L_{Aeq,8h} = L_{EX,8h}$ (dB(A))	$L_{EX,ppeak}$ (dB(C))	$L_{Aeq,Te}$ (dB(A))	$L_{EX,ppeak}$ (dB(C))	$L_{EX,8h}$ (dB(A))
1 Packaging operator	86.7	127.5 ($T_e=8$ h)	89.0 ($T_e=40$ min)	137.4 ($T_e=40$ min)	86.0
2 Packaging operator	86.8	115.7 ($T_e=8$ h)	89.3 ($T_e=52$ min)	123.2 ($T_e=52$ min)	86.4
3 Packaging operator	86.1	119.7 ($T_e=8$ h)	88.6 ($T_e=57$ min)	137.2 ($T_e=57$ min)	85.8
4 Packaging operator	88.1	120.3 ($T_e=8$ h)	90.1 ($T_e=40$ min)	126.8 ($T_e=40$ min)	87.8

The readings obtained with dosimeters confirmed that the workers who operate in the presses area (table 5) are subject to a higher daily exposure level than the people working in the storage/packaging area (table 6). Also, the levels obtained with readings extended to 8h are higher, although still comparable, with the $L_{EX,8h}$ obtained with shorter exposure times. However, it is evident that the workers are nearer to the machinery, and therefore subject to more noise than the data collection sites. The readings obtained from the fixed sites are more indicative of the environmental noise.

On the other hand, the difference between phonometer and dosimeter data imposes the following consideration. Independently of the fact that the dosimeters are or are not Class I, in many cases the equipment for taking personal readings cannot be controlled by the researchers, or by the workers who wear it. For reasons of comfort or the demands of their work, workers are often forced to move in such a way as to stress the microphones in a different way from acoustic pressure. So in this specific case, the noise levels which are most indicative of the situation in the factory are those registered by the phonometers, also because anomalous behaviour by workers cannot influence these levels. The consequence is that in these factories, evaluation of noise risk must always be carried out by comparing personal readings with readings from fixed sites.

Evaluation of dust risk

The readings of PM10 concentration in the air, carried out by the samplers, are shown in table 7. We can see a positive situation, since the levels of PM10 at every site are much lower than $0,5 \text{ mg/m}^3$, level given by the ACGIH, that is to say the maximum concentration allowed, weighted in the time of 8h (TLV-TWA). To this concentration of total dust, almost all the workers may be repeatedly exposed, without harmful effects due to the flour dust.

This is related to the efficiency of the extractor fan system, which does not allow the dust to deposit on the floor, intervening rapidly to reduce the risk for the workers on the dust way towards the air outlets. In fact, peaks of dust production are measured for very short periods of time, about 5 min, which do not in any case exceed the TLV-TWA and are reduced to lower levels in equally short periods (figure 2).

Table 7. PM10 concentration in air measured by fixed samplers taken in the three investigated working areas.

TLV - TWA	Sample point number (figure 1)					
	1 (Presses Short pasta)	2 (Presses Long pasta)	3 (Drier/silo Short pasta)	4 (Drier/silo Long pasta)	5 (Packaging Short pasta)	6 (Packaging Long pasta)
0.5 mg/m^3	$0,005 \text{ mg/m}^3$	$0,002 \text{ mg/m}^3$	$0,005 \text{ mg/m}^3$	$0,002 \text{ mg/m}^3$	$0,004 \text{ mg/m}^3$	$0,006 \text{ mg/m}^3$

Relatively greater production of PM10 takes place in the packaging area, where there are higher levels on the long pasta line; it is evident that more dust is produced when working with the dry product. Indeed, the start of the packaging line is an "open section" of the system; the product emerges from the drying and storage tunnel (figure 1), where dust accumulates because the space is confined and insulated up until the outlet section. On the long pasta lines, the product also needs to be laid flat and cut before packaging; this creates more dust and scraps, which are shredded and then recycled at the head of the system.

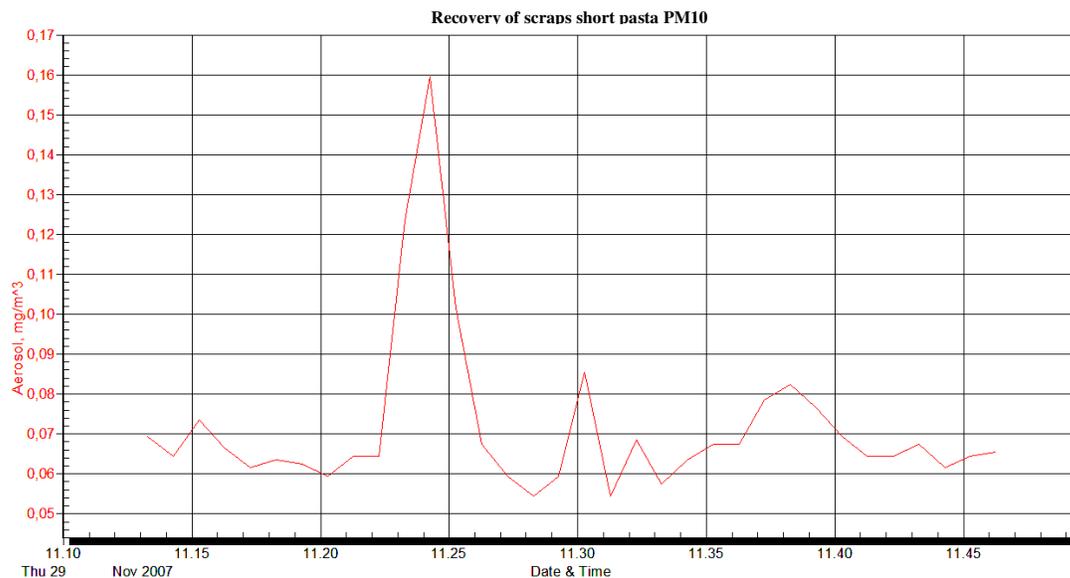


Figure 2. Example of measurement of PM10 concentration in air versus time, by direct-read dust analyser, taken in the sample point 3 between drier and silo of short pasta line (Figure 1).

Finally, we must consider that packaging involves some complex operations, like the preparation and filling of the packages and transport by mechanical equipment in constant movement, as well as grinding and pneumatic conveyance of the contents of failed packages.

However, in this kind of food production, periodic monitoring of factory dust must be carried out in order to check the efficiency of the extractor systems and to avoid risks of allergies caused by dust inhalation. It is important to check the workers' breathing, and in cases where there are workers with flour asthma, to evaluate the different factors which can influence the course of the illness. In fact, it should be said that exposure to respirable semolina dust is an allergy risk factor even at levels of much less than TLW, due to a particular subjective proneness: recent studies indicate that exposure to wheat flour sensitises 11.5% of subjects, and causes respiratory problems in 12÷18,5% and work-related asthma in 5÷7% (Becklake M. et al. 1997; Benvenuti F. et al. 1998).

Conclusions

The PROGESA Department and the Department of Internal and Public Health have been carrying out a research programme for several years which aims to provide guidelines for evaluation of risks in workplaces in the livestock farming and food sectors. An interdisciplinary approach is needed to evaluate risks to workers' health and safety in their workplaces, bringing together the results of research in different sectors. In addition, the risk factors are influenced by numerous variables, which are difficult to control because they depend on both technical and human factors. Moreover, the results obtained in the laboratory must, in any case, be checked with trials carried out in the workplace – without interference, damage or changes to the firm's production cycle.

Finally, the solutions proposed must relate to the economic situation of the firms, knowing that in some cases it is difficult - or even impossible - to remove every risk. The technicians who are responsible for various levels of prevention are also asked to achieve partial objectives, at the best cost (which does not always coincide with the lowest cost) and maximum benefit.

The results of the research carried out in the present work confirm the validity of the general considerations stated above, for the pasta sector of the food industry, also in the light of the complex legal requirements.

There was a problem concerning methodology and approach in the evaluation of noise risk, because this work involved noise levels at the limits of what the law allows. It was evident that correct definition of legal requirements and evaluation of effective exposure to noise required phonometer readings taken at fixed sample points and also dosimeter readings from individual workers; the former for dealing with the production cycle and machinery, and the latter for task management. If the results are read without taking into account the reality of the situation, they can appear incongruent and worrying; but they allow us to state that, in this factories, the management of this kind of risk factor requires the employer to carry out continuous monitoring of the environmental data, maintenance and turn-over of the machinery and systems, and continuous personnel training and appropriate assignment of tasks.

A similar commitment is necessary to manage the risks deriving from exposure to dust particles. In this kind of firm this risk factor is low, and is caused by machines and stages in the production cycle which do not produce high noise. On the other hand, the efficiency of the air extractor system is fundamentally important, because it is possible for workers to develop respiratory diseases caused by allergic reactions to semolina dust.

Acknowledgements

The Authors wish to thank Riscossa Pasta factory F.lli Mastromauro S.p.A for allowing the study and for collaborating on the experimental trials.

References

- ACGIH, CINCINNATI OHIO. 2006. TLVs and BEIs based on the documentation of the Threshold Limit Values for chemical substances and physical agents & Biological exposure indices.
- Ames R.G. 1991. Multiple episode conjunctivitis outbreak among workers at a nut-processing facility. *Journal of Occupational Medicine*, 33:4, 505-509.
- Becklake M., Broder I., Chan-Yeung M. (1997), Recommendations for reducing the effect of grain dust on the lungs, *Occupational Health and Industrial Medicine*, Vol. 36, Issue: 2.
- Benvenuti F., Lombardi R., Pastoni F. 1998. Il rischio e la pianificazione degli interventi di prevenzione e protezione. ISPESL - Dipartimento di Igiene del Lavoro.
- Cappelli P., Vannucchi V. 2000. *Chimica degli alimenti – Conservazione e Trasformazione*. Zanichelli.
- Cascone G., Fichera A., Lanteri P., Marletta L. 1996. La problematica del rumore negli ambienti di lavorazione degli agrumi. Quaderno n. 18 della Rivista di Ingegneria Agraria, Atti del Seminario di Studio della II e VI Sezione Tecnica dell'A.I.I.A.: "Costruzioni ed impianti per la conservazione e trasformazione dei prodotti agricoli", Selva di Fasano (BR), 20-23 Settembre 1996.
- Cassano F., Sancilio C., Ruggiero G., Massola A., De Marinis G., Rubino G. (2000), Risks of working in a fruit and vegetables factory during the preparation of actinidia, The XIV Memorial CIGR World Congress, November 28 – December 1, Tsukuba, Japan.
- Di Candia E., Mongelli C. 1996. "Analisi e valutazione del rischio da "rumore" negli oleifici", Quaderno n. 18 della Rivista di Ingegneria Agraria, Atti del Seminario di Studio della II e VI Sezione Tecnica dell'A.I.I.A.: "Costruzioni ed impianti per la conservazione e trasformazione dei prodotti agricoli", Selva di Fasano (BR), 20-23 Settembre 1996.
- Jayawardana P. L., Udupihille M. 1997. Ventilatory function of factory workers exposed to tea dust, *Occupational Health and Industrial Medicine*, Vol. 36, Issue 6.
- D.M. 25/11/1994, S.O. G.U. 13/12/1994 n. 290.
- Directive 99/30/CE, G.U.C.E. 26/09/1999 n. L 163/41 del.
- D.M. 2/04/2002, n.60 S.O. G.U. 13/04/2002 n. 87.
- Matteucci D., Rabazzi S. 2007. *La gestione dell'impresa alimentare*. EPC libri.
- Merseburger A. 1996. Repetitive movements of the upper limbs: Results of exposure assessment and clinical tests among workers sorting and packing apples. *Medicina del Lavoro*, 87 (6), 603-612. "Testo Unico Salute e sicurezza sul lavoro", Decreto Legislativo n. 81 del 9/04/08, S.U. G.U. 30/04/08
- Zock J. P., Heederik D., Kromhout H. 1995. Exposure to dust, endotoxin and micro-organisms in the potato processing industry, *The Annals of Occupational Hygiene*, 39, Issue 6, December.

The authors equally contributed to the present study.

International Conference: September 15-17, 2008 Ragusa - Italy
“Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems”

POSTER PRESENTATION

Acoustic levels in the manufacture of wood chairs

Zimbalatti G., Proto A. R., Morabito S.

Dept. Agroforestry and Environmental Sciences and Technologies (DiSTaFA)

Mediterranean University of Reggio Calabria, Italy - Reggio Calabria - 89122 Feo di Vito

E-mail: gzimbalatti@unirc.it; andrea.proto@unirc.it; stefano.morabito@unirc.it

Abstract

The legislative decree 195/2006 has implemented the European Directive 2003/10/CE about noise exposure of workers and it has introduced a series of articles defining health and safety standards. The sector of wood processing is one of the most concerned by such a problem; in particular, the highest number of recognized cases of hypoacusia and deafness occur in furniture factories. As a result, a study was carried out on the acoustic levels in some Calabrian secondary wood industries manufacturing predominantly chairs, but also tables and other wood furniture. The acoustic survey was carried out under full and normal operating conditions of the industries; after evaluating the residence times of workers in their work station, the level of daily personal exposure was estimated. The examined industries do not always comply with the ergonomics and safety standards established by law for an acoustic comfort meeting workers' needs. Such interventions take into account the change of the lay-out of the production cycle, the reduction of acoustic emissions directly at their sources, an effective organization of work and a greater awareness towards the use of personal protection devices.

Keywords: acoustic pollution, noise reduction, safety, wood processing.

Introduction

The Calabrian forest resources play a role of primary importance for the regional economy; Calabria is, in fact, one of the first regions in Italy for its forest surface, its woodland index and its yearly wood manufacture. The quantity of timber processed every year is 10% of the whole Italian sector of wood transformation. The wood transformation industries which have been involved survive thanks to their flexibility and adaptability. In particular, these industries keep on covering special niches in the marketplace, such as furniture industries and hand-made carpentry, where quality productions and order productions are very important (Zimbalatti *et al.*, 2005). In Calabria the wood industry, furniture included, takes up over 20.000 workers (Istat, 2001). In particular, the furniture manufacture in Calabria reaches a point of excellence in the area of Serrastretta, a village known as 'The city of the chair', which boasts a consolidated tradition for the manufacture of chairs and other items. In this mountain centre there are several small and medium size factories, that follow an important hand-crafted tradition, and with their very valuable products they manage to keep significant market shares, in spite of the keen competition of the sector. On the technical level, the cycle of the factories manufacture, which gets inspiration from the hand-crafted tradition, is today nearly wholly mechanized. The good levels of productivity achieved, must not allow to under estimate the risks for the health of the workers who work in these factories. In particular, the process of mechanization of the manufacture processes has led to an increase of the noise sources and, as a result, of an increase of the percentage of workers exposed to this risk. Not by chance, in the wood macrosector, the majority of recognized cases of hypacusia and deafness take place in furniture factories; still, the index of frequency is not particularly high (Verdel *et al.*, 2001).

Materials and methods

The sector of wood transformation is traditionally marked by high levels of exposure to noise, due to a series of attendant circumstances, such as the use of facilities with high acoustic power in often narrow work environments (Piccioni R., 2006). Starting from these considerations, the Mechanical Section of the DiSTA/A of the Mediterranean University of Reggio Calabria, which has been interested in research themes about safety at work for years, has carried out a survey about acoustic levels in some secondary wood industries manufacturing chairs, tables and other wood furniture items.

The legislation reference

The legislation about noise pollution has been recently changed. The D. Lgs. 195/2006, in fact, has changed the D. Lgs. 626/94. The title has been replaced by the Title V-bis, which regards the rules for the accomplishment of the “Protection from Physical Agents” at work. In particular, it has received and accomplished the European Directive 2003/10/CE on the workers’ exposure to noise, and it has introduced a series of articles which define the minimum requirements for health and safety with regard to exposure to noise. First of all, the limit of daily exposition to noise decreases from 90 to 87 dB(A); this limit considers also the noise reduction produced by the personal protective equipment (PPE) worn by workers. Moreover, the peak level of impulsive noise is measured by the weight curve C, instead of the linear system. The maximum value of exposure to noise beyond whom it is obligatory to signal and/or to define the borders of the area, decreases from 90 to 85 dB(A); finally, the evaluation of noise considers also the possible interactions with vibrations or hearing toxic substances (Casini S., 2006). The new legislation defines, coherently with what said before, two values of reference: the **maximum value of exposure**, that is the level it is not possible to exceed, and the **action values**, lower and higher, that have to be considered by the employer to take specific protection measures for workers; in particular, if the lower value is exceeded, activities of “information, formation and PPE supply” must be carried out; if the higher value is exceeded, actions of “information, training and PPE supply with the obligation of use” are needed (Table 1).

Instrumentation and test parameters

The researches have been carried out with the use of a precision integrator phonometer Delta Ohm HD 9020. This instrument is set every year at the laboratory S.I.T.; before and after each daily series of measurements, the calibration has been controlled by a calibrator Delta Ohm HD 9101. The collected data have been transferred through a serial cable to a laptop to be processed successively. The modalities of measurement and the methodology of research include the arrangement of the instrument, through a special tripod and a bracket with a feeler, at the height of the operator’s ear, and at such a distance from his head, so as to reduce, as much as possible, the effects of diffraction and the distance of the measured value. The tests, have been carried out during full activity and normal operating conditions of the industries and, after evaluating the workers’ residence time in their work stations, the level of daily personal exposure has been calculated ($L_{EX, 8h}$).

The knowledge for each worker of the level of exposure and the value of peak acoustic pressure makes possible to verify the respect of the limit values established in the art. 49-*quater* of D.Lgs. 195/06, to decide the prevention and protection measures to be taken. Moreover, it is very useful to estimate also the uncertainty related to the level of daily personal exposure, to define if a specific limit of exposure is, or can be exceeded.

$$\text{Level of daily personal exposure} = L_{EX,8h} = L_{Aeq,Te} + 10 \log \left(\frac{T_e}{T_0} \right) \quad (\text{dB(A)})$$

$$\text{where: } L_{Aeq,Te} = 10 \log \left\{ \frac{1}{T_e} \int_0^{T_e} \left[\frac{P_A(t)}{P_0} \right]^2 dt \right\} \quad (1)$$

T_e = daily period of a worker's personal exposure to noise;
 T_0 = 8 hours;
 P_A = instantaneous acoustic pressure (weighting scale A), in Pa;
 P_0 = 20 μ Pa.

Table 1. Main differences between the old and the new legislation

Estimated provisions	D.Lgs. 277/1991	D.Lgs. 195/2006
Periodicity for noise evaluation	No	4 years
Interaction with vibrations and hearing toxic substances	No	Yes
Areas to be signaled/boundaries to be defined	≥ 90 dB(A)	≥ 85 dB(A)
Measure of peak level	dB(lin)	dB(C)
Lower value of action	85 dB(A)	80 dB(A)
Higher value of action	90 dB(A)	85 dB(A)
Maximum limit of exposure	90 dB(A)	87 dB(A)
Training for the use of PPE	≥ 85 dB(A)	≥ 80 dB(A)
Register of statements	Yes	No

Reduction of personal protective equipment

The new legislation imposes the employer, in case of exposure beyond the maximum value of 87 dB(A), to check the efficiency of the devices of hearing individual protection. So, during the tests in the different factories, the indications given by the D.M. 02/05/01 which fix the standards for the identification and the use of hearing protection devices through the reception of the rule UNI-EN 458 (Table 2), have been applied.

The action level (L_{act} - 85 dB) is the value beyond whom the employer make sure all workers wear PPE when noise levels are over 85 dB(A). In case the valuation points out an insufficient protection, it is necessary to use another kind of hearing protector with a higher reduction. On the contrary, if the valuation reveals that the protection effect is too high, it is necessary to use a different PPE with a lower reduction: we know indeed that hyperprotection can cause feelings of isolation and difficulty to perceive sounds. So it is necessary to make sure that the protection offered by the PPE stays in the limits of acceptance according to table 2. To verify the suitability of a PPE there are several methods based on the level of knowledge of the peculiarities of the environment noise and the values of acoustic reduction provided by the constructor of the device, together with the mark CE.

The method used in this research for the evaluation of the efficiency of PPE, is the system of simplified reduction of noise level - SNR (Simplified Noise Reduction) - that uses the equivalent level of acoustic noise pressure according to curve C. Successively, the equivalent

level for each worn device (L'_{Aeq}) has been compared to the action level to evaluate the suitability of the hearing protector itself.

$$\text{Real level at the ear} = L'_{Aeq} = L_{Ceq} - \text{SNR} \quad (2)$$

where:

L_{Ceq} = Equivalent level of acoustic noise pressure according to weighting scale C;

SNR = Value of acoustic reduction per octave band of a hearing protector.

Table 2. Evaluation of acoustic reduction

Real level at the ear	L'_{Aeq} dB	Evaluation of protection
Higher than L_{act}	80	Insufficient
Between L_{act} and $L_{act} - 5$	80 - 75	Acceptable
Between $L_{act} - 5$ and $L_{act} - 10$	75 - 70	Good
Between $L_{act} - 10$ and $L_{act} - 15$	70 - 65	Acceptable
Lower than $L_{act} - 15$	65	Too high (<i>Hyperprotection</i>)

Examined factories and production cycles

In the geographical area interested by this research there are today about thirty small enterprises, which produce in the average 70.000 chairs a year with a consolidated tradition, that comes from the use of wood of the renowned "Faggeta di Serrastretta".

The tests have been carried out in three factories ("A", "B", "C"), specialized in the manufacture of chairs, tables and other wood items (Table 3). In these factories, that are representative of the whole production area, the cycle is nearly fully mechanized; the work lines are composed of different kinds of machines. The work cycle can start from both sawed and unfinished products. In any case, the work diagram is articulated as follows:

- **Transverse sawing:** this operation, which is carried out by the band saw, enable to make useful pieces for the furniture manufacture from sawed products.
- **Shaping/planing:** the pieces coming from the sawing are subjected to the shaping or the planing. In particular, wood pieces are given a form or a non-rectilinear contour by the shaping. On the contrary, by the planning, pieces are given the wanted dimensions and smoothing. Shaping is made by two kinds of machines: la slides compound saw and the vertical axle moulder (*toupie*). For linear pieces the shaping is made by the planer.
- **Sanding:** Shaped wood pieces are smoothed. This operation is made by orbital sanders and band sanders.
- **Drilling:** shaped and smoothed pieces are joined together by the tenone joint and the mortase. The joint is a slot of wood pieces with prominences and pieces with complementary creaks. Prominences are called tenones, creaks are named mortases. Mortases are made by the mortising machine; tenones are carried out by the tenoning machine. Moreover, tenones are subjected to the knurling, which imprints on them splines that support the successive glueing operation. This operation is made by the knurling machine. The screws holes are made by drilling machines.

- **Frame assembly:** the furniture frame is made by joining wood pieces manually by the tenone joint and the mortase. With regard to chairs, the operators put the frame on the narrow passage, a facility that makes a pressure on specific parts of the manufactured item to make it steady.

Table 3. Peculiarities of the examined factories

Peculiarities	Factory		
	A	B	C
Number workers	6	6	5
Yearly production			
• chairs	25.000	12.000	20.000
• tables	5.000	3.000	1.000
• benches	-	1.000	-
• stools	-	4.000	-
Surface factory (m ²)	1.100	2.000	800

Results

In tables 4, 5 and 6 you can see the results of measurements and the processing activities carried out in each factory in the different work stations. The machines working wood through the shaving removal by tools, disks or rolling knives at a high speed, give out high acoustic levels, especially if they are not well used and repaired. In no station the value of $L_{peak}(C)$ came out higher or equal to 135 dB(C), so the verification of the respect of the action values and the exposure limits has been carried out exclusively on the base of the values of the daily personal exposure $L_{EX,8h}$.

In particular, in the machines for the drilling and the sanding, in the three factories, the equivalent levels are equal and sometimes higher to 85dB(A). As a result, the values of the daily personal exposure in a period of eight hours are different in the three examined factories. Indeed, for the 47% of the 17 examined workers the maximum exposure value of 87dB(A) is exceeded, and the choice of PPE does not seem to be satisfying (Figure 1).

In factory A, lower action values, 80 dB(A), have been exceeded in all work stations leading the worker to supply protection devices. In particular, five workers are subjected to acoustic levels higher than 85 dB(A), high action value which, not only forces workers to wear PPE, but also imposes the employer to create and apply a specific programme of technical and organizing measures to reduce this exposure. All workers have been provided with auricular insets with an arc of 3M model 1310, certificated according the norm EN 352-2. The test of the reduction produced by these PPE shows as the use of insets is excessive for the operator 1, insufficient for the employer A6, while it is acceptable for all other workers. The acoustic values given out from the mortising machine are outlined. They are the highest of the whole factory because of the old age of the machine, the bad conditions of maintenance and his closeness to walls (Figure 2). The factory, therefore, does not comply with the minimum requirements for an acoustic comfort; the overcoming of limit values found in all machines must induce the employer to reconsider the factory layout, its management and maintenance, and incidentally think about the replacement of some machines (ex. the mortising machine).

In B, acoustic levels do not exceed 80 dB(A), except the tenoning machine which reaches 95 dB(A). This factory has clearly better acoustic conditions compared to the

previous one; in fact, only one person works in conditions that exceed the legal limit value (Figure 2). The factory has only one machine which exceeds the limits fixed by law; so it could be separated from the other machines by plastic vertical strips (Windor Strips), already applied with success in bottling factories (Febo e Orlando, 2002). The low cost, the facility of maintenance and the good functionality make it an applicable solution compared to more complex reorganization interventions. Anyway, the noticed exceeding value would demand the creation of an access limited area defining its borders and limiting the access only to workers with appropriate individual protection devices. The values of daily personal exposure, according to what has been said, are, except operator B5, lower than legal values both for the excellent machines arrangement and their conditions of technical efficiency. The reduction produced by earphones - 3 M 1435 - in favour of the two workers (B5-B6), subjected respectively to values higher than 90 and 80 dB(A), is acceptable.

The data collected in enterprise C show quite different acoustic levels (Figure 2); there are machines with values higher than 87 dB(A), in comparison with other machines which have values around 80 dB(A). In particular, high levels have been registered near the planer (97,7 dB(A)) and the unframing machine (95,9 dB(A)). Other machines with high acoustic levels, according to the present legislation, are the tenoning machine, with 89,1 dB(A), and the mortising machine with 86,4 dB(A). Inside this factory, workers change their task every two hours; by this choice, the employer means to guarantee a complete shift rotation of work burdens; this situation affects, therefore, the levels of personal exposure to noise, as well. This management of work tasks exposes all workers to acoustic levels, which are always higher than the maximum exposure limit, and obliges them, in the same way, to the use of PPE, that are however appropriate to reduce these levels. Indeed, the choice of the earphone (Twin Mark 12), used by this factory, appears to have good reducing levels. It could be useful, in addition, to isolate acoustically the machines with higher emission levels. It would be also necessary to draw attention on the work areas where this machines work, as they exceed of 10 dB the medium values, to warn the operator about the importance of using PPE.

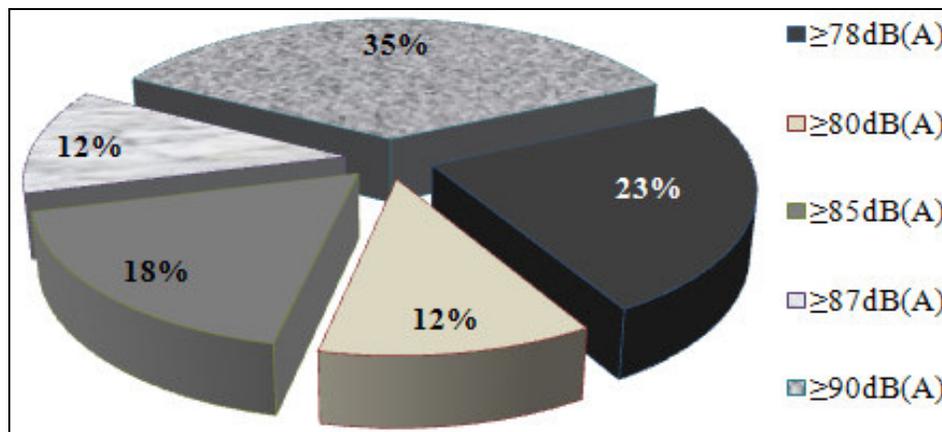


Figure 1. Distribution of workers according to personal exposure

Table 4. Acoustic levels in factory A

Work station	$L_{eq,i}$ (ε)	L_{peak} (dB)	Operator				
			A1	A2 – A3	A4	A5	A6
			Residence time t_i (hours)				
1. Band saw	86,5 (± 0,4)	112,4		8,00			
2. Trimmer	88,9 (± 0,6)	113,7				4,00	
3. Unframing machine	77,2 (± 0,6)	108,3	4,00				
4. Toupie	83,3 (± 0,4)	111,7	4,00				
5. Planer	86,2 (± 0,1)	113,5			4,00		
6. Sander	85,2 (± 0,1)	112,9			4,00		
7. Tenoning machine	84,4 (± 0,3)	110,8				4,00	4,00
8. Mortising machine	103,8 (± 0,3)	139,1					4,00
$L_{EX,8h}$ [dB(A)]			81,2	86,5	85,7	87,2	100,8
$\epsilon L_{EX,8h}$ [dB(A)]			± 0,8	± 0,8	± 0,7	± 0,9	± 0,8
Level of exposure with PPE			62,0	68,0	67,0	68,0	82,0
Reduction			Too high	Acceptable	Acceptable	Acceptable	Insufficient

Table 5. Acoustic levels in factory B

Work station	$L_{eq,i}$ (ε)	L_{peak} (dB)	Operator				
			B1	B2 – B3	B4	B5	B6
			Residence time t_i (hours)				
1. Band saw	78,3 (± 0,3)	106,5		5,00			
2. Alternate saw	80,0 (± 0,9)	107,9				4,00	
3. Unframing machine	79,3 (± 0,5)	108,1			8,00		
4. Toupie	77,2 (± 0,4)	106,9	2,00	3,00			
5. Planer	80,3 (± 0,4)	111,4	6,00				
6. Sanding	79,8 (± 0,1)	111,1					4,00
7. Tenoning machine	95,0 (± 0,2)	119,8				4,00	
8. Mortising machine	80,5 (± 0,5)	109,1					4,00
$L_{EX,8h}$ [dB(A)]			79,7	77,9	79,3	92,1	80,2
$\epsilon L_{EX,8h}$ [dB(A)]			± 0,8	± 0,8	± 0,9	± 0,7	± 0,8
Level of exposure with PPE						77,0	66,0
Reduction						Acceptable	Acceptable

Table 6. Acoustic levels in factory C

Work station	$L_{eq,i}$ (ε)	L_{peak} (dB)	Operator				
			C1	C2	C3	C4	C5
			Residence time t_i (hours)				
1. Band saw	81,3 (± 0,6)	109,8	2,00	2,00			
2. Unframing machine	95,9 (± 1,4)	120,9		2,00	2,00	2,00	
3. Toupie	80,3 (± 0,6)	109,5	2,00			2,00	
4. Planer	97,7 (± 0,5)	122,4	2,00				2,00
5. Sander I	80,4 (± 0,2)	108,7			2,00		
6. Sander II	77,7 (± 0,3)	106,5		2,00		2,00	4,00
7. Tenoning machine	89,1 (± 0,6)	118,5			2,00	2,00	2,00
8. Mortising machine	86,4 (± 0,4)	115,9	2,00	2,00	2,00		
$L_{EX,8h}$ [dB(A)]			88,0	90,5	91,2	90,9	92,4
$\varepsilon L_{EX,8h}$ [dB(A)]			± 0,9	± 1,6	± 1,5	± 1,5	± 0,9
Level of exposure with PPE			70,0	73,0	73,0	73,0	74,0
Reduction			Acceptable	Good	Good	Good	Good

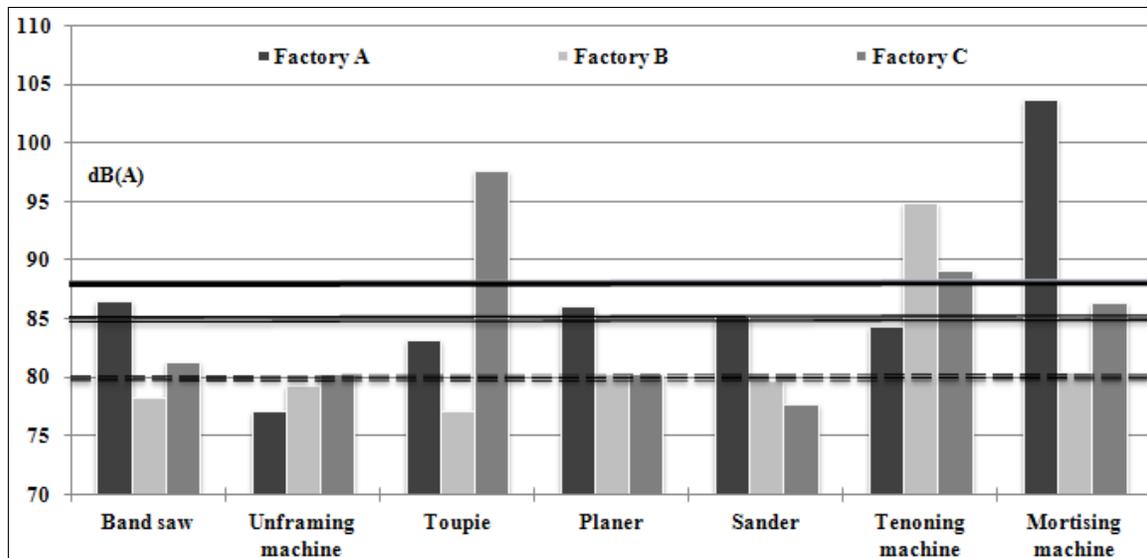


Figure 2. Equivalent levels in the examined machines

Conclusions

The phonometric data processing has enabled to outline a general picture, even though approximate, of the acoustic conditions of the three considered factories, with reference to the monitored mountain areas. Unfortunately, it has turned out that the non-reception and non-application of the present legislation endangers the safety of workers, who, in most cases, are unaware of the risks they run. In the work stations where there is an equivalent acoustic level higher than 85 dB(A), it would be important to adopt specific balancing measures or precautionary interventions, and limit the access only to the employers with appropriate personal protective equipment, as well (earphones or auricular insets).

The noise reduction, at the source or on the run, should be one of the main management programmes of this risk factor. This activity must take into account both the facilities and planning, as well as maintenance to control acoustic pollution inside factories during the cycle of wood processing. The clearing of work stations can be positively carried out by limiting the productive lines in soundproofing cabins and tunnels, and coating the plates subjected to impacts (Bianconi A., 2004). With regard to work places, there is in all three factories, a complete saturation of spaces. The acoustic field is the sum of the direct field and the one reflected by walls. To eliminate the latter, it is reasonable to put appropriate soundproofing panels hanging from the roof and applied to the factory walls. In general, the visited enterprises rely on the supply to workers of the different kinds of PPE hearing protectors in commerce for the protection from noise. But with regard to legislation, it is important to remember that no auricular protection is valid everywhere. It is necessary to know the peculiarities of noise in the different environments where people work, to choose the right acoustic damping factor. It is also important to consider the length of stays in particularly noisy environments. In some cases, if hearing is not constantly protected, it risks permanent damages.

References

Bianconi A., 2004. Valutazione all'esposizione a rumore e vibrazioni in alcune PMI umbre operanti nel settore legno. 3° Seminario dei professionisti CONTARP "La prevenzione che cambia. I ruoli, le strategie e le sinergie degli "attori" coinvolti".

Caporale R., Bisceglia M., 2003. Le Ipoacusie da rumore in ambito INAIL: aspetti medico-legali. Sovrintendenza Medica Generale INAIL.

Casini S., 2006. Da dicembre meno rumore in azienda. Dati Inail sull'andamento degli infortuni sul lavoro, n°12.

Cassano F., Bavaro P., Aloise I., Dal Sasso P., Ruggiero G., 2005. Problematiche connesse all'inquinamento da polveri e da rumore in un opificio per la lavorazione delle mandorle. Atti del Convegno AIIA "L'ingegneria agraria per lo sviluppo sostenibile dell'area mediterranea", Catania 27-30 giugno.

Decreto Legislativo del 10 aprile 2006, n. 195 Attuazione della direttiva 2003/10/CE relativa all'esposizione dei lavoratori ai rischi derivanti dagli agenti fisici (rumore).

Febo P., Orlando S., 2001. Interventi per ridurre la rumorosità all'orecchio degli operatori di una cantina con due linee di imbottigliamento. Rivista di Ingegneria Agraria, n°4, 244±252.

Giametta F., Proto A.R., Zimbalatti G., 2007. Analisi dell'esposizione al rumore nelle industrie di prima trasformazione del legno in Calabria, Sherwood – Foreste ed Alberi Oggi n°129, - Mensile di divulgazione tecnico-scientifica della Compagnia delle Foreste.

Piccioni R., 2006. Bonifica acustica nelle aziende di trasformazione del legno. Dati Inail sull'andamento degli infortuni sul lavoro, n°11.

Verdel U., Iotti A., Piccioni R., 2001. Danni professionali da rumore e vibrazioni nel periodo 1989-1999. Atti del seminario nazionale "Linee guida ISPESL sull'esposizione professionale a rumore e vibrazioni Roma, 30 gennaio.

Zimbalatti G., Proto A.R., Abenavoli L.M., 2005. Impianti e cicli produttivi in segherie calabresi. Atti del Convegno AIIA "L'ingegneria agraria per lo sviluppo sostenibile dell'area mediterranea", Catania 27-30 giugno.

Zimbalatti G., Zema D., 1999. Research into environmental noise in continuous cycle oil mills. Proceedings of XXVIII CIOSTA-CIGR V Congress, Horsens, Denmark, 14-17 giugno, 244±249.

The authors participated equally in all the phases of the present work.

Risk profiles for workers involved in meat transformation processes

Porceddu P. R.¹, Rosati L.¹, Dionigi M.²

¹*Dept. of Agricultural and Environmental Sciences, University of Perugia, Borgo XX Giugno 74, Perugia, Italy, tel. +39 75 5856079, fax +39 75 5856440, porceddu@agr.unipg.it*

²*Dept. of Geology and Mechanical, Naturalistic and Hydraulic Engineering for the Territory, University of Tuscia, Via De Lellis, Viterbo, Italy, tel +39 761 357357, ergolab@unitus.it*

Abstract

In recent years the pig sector has registered the evolution from farm involved in breeding, to farms specifically dedicated to meat transformation. Accordingly the transformation process is completely accomplished by machine.

The present paper reports an evaluation of the relationship between the production process and risks to the workers' safety. Particular attention was paid to the manual material handling.

By using the NIOSH method it emerged that health surveillance must be taken into account.

Keywords: workers' safety, ham production.

Introduction

In livestock compartment of Umbria Region the pig sector plays a particularly significant role for both the high incidence on Gross Saleable Production of the regional animal husbandry and the historical tradition of this type of farming, as witnessed by many companies operating in transformation of pork meat.

In many cases the factories have evolved changing their dimensions from small and medium-sized, carrying out most of the breeding and processing to larger companies dedicated to processing phase. The reduction of factories engaged in breeding and more generally the decrease in the number of animals were substantially due to issues on environmental impact, linked both of wastewater and odours.

Various technological innovations (i.e. the use of machines) have been introduced in the production process of ham, in the past carried out by hand. These changes facilitate workers at work, but machinery use new risks for workers determines. The aim of this work is to determine the relationship between the production process and risks to the workers' safety.

Materials and methods

Several visits in a ham in the province of Perugia were realized, in order to analyse the different phases of production and therefore evaluate the possible risks to the workers' safety.

The building consists of two levels: the ground floor used for the receipt and processing, and the underground floor housing the seasoning. The two floors are connected by stairs and a lift. The area of work presents quartz floors, washable walls and adequate lighting, not altering the colour of the food. To prevent insect infections the windows are equipped with net and the doors are with seals.

All rooms intended for pre-seasoning, seasoning and storage of the finished product have door, insulated walls and ceiling, all washable.

The forwarding area is located in the front of the establishment. A sink with foot pedal, soap dispenser and drying hands papers, are present in the processing area.

The rooms for maturation and local of packaging, are equipped with a transport system located on the ceiling. It consists of guides on which steel frames that support the hams flow.

This system makes quick transportation of ham and air circulation between them. Finally, all the staff's toilets and changing rooms are suitably located and separated from production areas.

The factory processes 5×10^5 kg of meat deriving from national and abroad fresh pork hams with and without bone. After first visit particular attention was paid to the manual material handling and to the execution of the operations.

Such operations can be heavy and eventually lead to musculoskeletal disorders. The NIOSH (National Institute for Occupational Safety and Health) method was used to evaluate the Lifting Index as:

$$LI = LW \text{ (Load Weight)} / RWL \text{ (Recommended Weight Limit)}$$

For $LI < 1$ do not have work at risk and need not be any health surveillance;
 for $LI \geq 1$ the work is at risk and require health surveillance.

The RWL is given by: $LC \times HM \times VM \times DM \times AM \times FM \times CM$
 in which:

- LC is load constant (tab. 1);
- HM is an horizontal multiplier, measured from the mid-point of the line joining the inner ankle bones to a point projected on the floor directly below the mid-point of the hand grasps (tab. 2);
- VM is a vertical multiplier, defined as the vertical height of the hands above the floor. It is measured vertically from the floor to the mid-point between the hand grasps, as defined by the large middle knuckle (tab. 3);
- DM is a distance multiplier, defined as the vertical travel distance of the hands between the origin and destination of the lift (tab. 4);
- AM is an asymmetric multiplier, is the angular measure of how far the object is displaced from the front of the worker's body at the beginning or ending of the lift, in degrees (measure at the origin and destination of lift) (tab. 5);
- FM is a frequency multiplier, defined by (a) the number of lifts per minute (frequency), (b) the amount of time engaged in the lifting activity (duration), and (c) the vertical height of the lift from the floor. It refers to the average number of lifts made per minute, as measured over a 15-minute period (tab. 6);
- CM is a coupling multiplier, is the judgement on the force a worker can or must exert on the object. A good coupling will reduce the maximum grasp forces required and increase the acceptable weight for lifting (tab. 7).

Table 1. Load constant

	Males	Females
Age	> 18	> 18
Load Weight [kg]	30	20

Table 2. Horizontal multiplier

Distance [m]	0.25	0.30	0.40	0.50	0.55	0.60	> 0.63
HM	1.00	0.83	0.63	0.50	0.45	0.42	0.00

Table 3. Vertical multiplier

Height [m]	0	0.25	0.50	0.75	1.00	1.25	1.50	> 1.75
VM	0.78	0.85	0.93	1.00	0.93	0.85	0.78	0.00

Table 4. Distance multiplier

Distance [m]	0.25	0.30	0.40	0.50	0.70	1.00	1.70	> 1.75
DM	1.00	0.97	0.93	0.91	0.88	0.87	0.86	0.00

Table 5. Asymmetric multiplier

Angle	0°	30°	60°	90°	120°	135°	> 135°
AM	1.00	0.90	0.81	0.71	0.62	0.57	0.00

Results

The raw material arrives to the factory through refrigerated trucks. This is thighs of adult pigs, except boars and sows coming from breeding of white races. The thighs have specific physical and organoleptic characteristics: no less than 13.5 kilograms weight, good looking and red colour.

The matter comes to the factory arranged on trolley having 7 platforms placed at different heights (one at 0.25 m from the other; the trolley is 1.85 m high). The thighs are weighed and transferred to a cell, where they stay for about 24 hours at a temperature between 0 and 4 °C (Fig. 1).

After 24 hours the salting operation is made by use of specific machines, consisting of a conveyor belt carrying the thighs inside the machine. At the beginning the product was stamped, after salt and other spices fall on it. In particular 2 workers, working at the entrance of the machine, manually take the thighs by trolley and put them on a conveyor belt; other 2 at the exit of the machine deposit thighs on empty trolley and finally a person carries trolleys empty and full (Fig. 2). In the case of thighs with the bone it is necessary to remove blood from main veins. This operation is carried out using a special machine, whose operating mechanism provides for the passage of thighs, through a series of rollers, which thanks to their particular shape carrying a gradual pressure. The salted thighs are then placed in special cells where they remain for 7 days at a temperature between 0 and 4°C.

Table 6. Frequency multiplier

Frequency	0.20	1.00	4.00	6.00	9.00	12.00	> 15.00
Duration < 1 hour	1.00	0.94	0.84	0.75	0.52	0.37	0.00
Duration from 1 to 2 hours	0.95	0.88	0.72	0.50	0.30	0.21	0.00
Duration from 2 to 8 hours	0.85	0.75	0.45	0.27	0.52	0.00	0.00

Table 7. Coupling multiplier

Judgement	good	low
CM	1.00	0.90

After this period, the hams are desalted and salted again, and then reintroduced in cells for 11 days at temperature between 0 and 4 °C. Salt elimination (desalting) and drying with a machine driven air pressure. The eliminated salt is recovered and used again. The second salting operation is carried out as the previous one. After this phase the meat is desalted again and incubated for 15 days in a ventilated cell (T = 3.5 ÷ 4.5 °C - Humidity 45 ÷ 65%). After that period the hams are transferred to a not ventilated cell (T = 2.5 ÷ 5.5 °C - Humidity 62 ÷ 68%) and then finally to a ventilated cells for 70 days (T = 2.5 ÷ 4.0 °C - Humidity 10%). The

wash step in a washing machine follows. The hams are washed with water and automatic brushes. The drying takes place in a special cell for a time of 7 days ($T = 18 \div 24 \text{ } ^\circ\text{C}$ - Humidity $55 \div 73\%$).



Figure 1. Detail of manual material handling.

The pre-seasoning follows and it lasts for a time of 3 to 4 weeks ($T = 16 \div 19 \text{ } ^\circ\text{C}$ - Humidity $72 \div 77\%$).

All next operations are entirely carried out by hand. First the ham is sprinkled with lard of semi-seasoned ham. This operation is performed by 2 operators and practically it is composed of several actions: i) taking of hams from steel frames; ii) the deposition of them on a table; iii) the heating of a solidified block of lard and; iv) the sprinkling of meat with a brush (Fig. 3-4). Finally the ham is rearranged on the steel frame. The cycle ends after thirteen months inside the maturing cells ($T = 16 \div 18 / 17 \div 18 / 17 \div 19 \text{ } ^\circ\text{C}$ - Humidity $70 \div 72\% / 67 \div 70\% / 58 \div 61\%$).

The last operations are packaging and forwarding. In detail on the transport system above described (guides and steel frame) the hams are transferred from maturing cells to the packaging area, where an operator climbs a ladder, takes the hams manually and puts them on a trolley.



Figure 2. Salting operation.

Meantime another operator opens the carton boxes and places one product for each box. The boxes are close weight and labelled, before storing them in a wooden bench. All the utilized machines were in accordance with the Italian Machinery Directive. The hand tools showed a clean conditions and were stacked in special shelves. During the operation of sprinkle with lard no safety problems for the operators emerged due to excessive heat. However there were risks for workers entering and exiting from the cells with various temperature and humidity values. The workers are urged to wear an additional clothes but due to hurry this action is seldom accomplished.

The biggest risk for workers is the manual movements of hams. The different operations are carried out using the same repetitive manual actions although with different frequencies. To calculate the NIOSH Index it was considered that:

1. "VM" factor was evaluated as the average between the different heights of thighs positioned on the trolley;
2. "AM" factor was evaluated equal to 0° because the shelves are arranged on the same line of the machine and therefore any twisting of the trunk is required by operator;
3. "CM" factor was judged "low" by data collector;
4. "FM" factor was resulted 0.21 (middle frequency of 12) for a continuous work from 1 to 2 hours. This interval for calculating the frequency has taken into account the diversification of the tasks performed by workers in the same work time.



Figure 3. Sprinkle of ham with lard.

To calculate the recommended weight limit the quantity of items moved in one working time (it is resulted: 2000) and the different weight of the thighs worked (75% of thighs with bone having 14.5 kg of weight, 25% of thighs without bone having 9.5 kg of weight) were considered. Therefore the RWL is 3.08 kg; the LI of the hams with bone is 4.75 kg; while the LI of hams without bone is 3.11 kg. The LI has been evaluated according to the quantity of different types of thighs worked:

$$\text{Total LI: } (4.75 \times 0.75) + (3.11 \times 0.25) = 4.33 \text{ kg}$$

Because the value obtained exceeds 1, the operations carried out in the factory determine a risk for the workers. Therefore health surveillance is necessary.



Figure 4. Movement of ham from and to steel frame.

Conclusions

The overall level of mechanization of the factory for hams production was good. Specific machines and a system of guides for the transport of thighs are adopted. However there was a problem of manual material handling. The survey conducted according to the NIOSH method showed a risk of musculoskeletal disorders for workers.

It is therefore necessary to do periodic health surveillance and especially a correct work organization based on appropriate shift. Therefore it is essential to train and inform on appropriate movements and on risks they have.

References

Waters T.R., Putz-Anderson V., Garg A., Fine L. 1993. Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics*, 36(7), 749-776.

Waters T.R., Lu M.L., Occhipinti E. 2007. New procedure for assessing sequential manual lifting jobs using the revised NIOSH lifting equation. *Ergonomics*, 50(11), 1761-1770.

Integrated approach to the safety of dairies through the use of check lists

Porceddu P.R., Rosati L.

Dept. of Agricultural and Environmental Sciences, University of Perugia, Borgo XX Giugno 74, Perugia, Italy, tel. +39 75 5856079, fax +39 75 5856440, e-mail: porceddu@agr.unipg.it

Abstract

The mechanization and plant engineering of agro-industries have made a notable contribution to the socio-economic development of industrialized countries and the consequent well-being of their populations. This has also led to an increasing need for improved working conditions for workers' safety. Quality management and quality assurance and environmental management are also issues that need to be taken into account. Therefore these systems have to match and coordinate each other. In the agro-industrial sector, small companies, often find it difficult to comply with such laws due to the family-centred organization of their production, the limited size of their farms, and the general absence of a real culture of work safety. This has resulted in a decrease in adequate investments due to the perception that there would be no immediate economic returns. The aim of this work is to evaluate the existing situation by adopting check lists with regards to workers' safety and health, quality management and quality assurance, and environmental management. With these check lists inspections were made in some dairies of the Umbrian region (Italy). The data gathered was elaborated and displayed by means of radar diagrams. The use of radar diagrams gave an immediate idea about the critical aspects that require urgent intervention so as to facilitate the planning of adequate investments with time.

Keywords: workers' safety, food quality, environmental management.

Introduction

Workers' safety at work is an important element to promote productivity and raise the quality of life. However, it is now necessary to address the security issue systematically, to assessing the implications of occupational safety, food security and environmental security. This implies the need therefore to consider a large number of laws in these three fields. For example, the Legislation of Machinery (DPR 547/55, DPR 459/96 etc...), the rules on food hygiene (Leg. 155/97, Regulation (EC) 178/2002), Environmental Standards (UNI EN ISO 14000, Leg. 152/2006, the provisions on waste water), etc...

In the field of small agro-business, for example it is necessary to consider local conditions governing the excellence and quality of their products. These businesses find themselves in difficulty in adapting to these laws. Because of the lack of appropriate organisational facilities, because family owner activities productions, with an inadequate organizational structure, they have slowed investment in this area, because it doesn't give immediate economic returns.

For example the dairy production, widespread in Italy, takes place throughout the entire year, with sustained work. In Umbria Region there are 25 companies (20 privately owned and 5 establishments cooperative entities) operating in the dairy sector, collecting a total of about 908,600 q milk annually, of which about half are used for transformation into cheese and the other destined for direct consumption.

In order to know the existing situation, but also to have a major tool easy to use, were developed a check list, which has carried out a series of surveys on such production. The aim is to know broadly the status quo in terms of job security, food security and environment. The

data collected were processed and displayed charts with radar, which has an immediate indication of the critical aspects which are most urgent and also the ability to plan over time an investment programme.

Materials and methods

The aim of this work is to define and apply the instrument of check list to companies in the dairy sector, allowing their evaluation of the risks to workers, major structural deficiencies and installation of establishments,

hygiene standards and quality for food and environmental implications.

In the province of Perugia, production units are more popular family-run, with fewer than 10 employees and have, in addition to its own outlet, a market concentrated in sales to shops, supermarkets, restaurants and pizzerias. In addition a summary was made of the general technical conditions of each of the establishments visited. In particular were found data on the general characteristics of dairy production, product quality, management of the safety of operators, the management of environmental security (use of alternative energy resources, possible control atmospheric emissions and management waste).

The development of a check list was used as a starting point this "macroindicatori" for the study of the existing legislation.

This "macroindicatori" specifies areas of investigation which has followed the development of a series of questions, which have been assigned a score, on the parameters: Relevance (A), efficiency (B), sensitivity socio-territorial (C) (regarding the environmental safety), relevance, management / organizational aspects technological / Structural (concerning food safety), relevance, management / organizational aspects technological / plant (regarding operator safety). For parameter "significance" means the importance of the appearance environmental safety / food / labour in the productive sector taken into consideration, namely the risk area of that (the dairy industry) to cause damage to environment, to food products, to the operator. For parameter "managerial / organizational" means the management of environmental, food and security for operators, namely the provision of tasks and responsibilities, training and training of personnel. For parameter "technology / equipment, technology / structural" shall mean the adjustment measures undertaken by the company in terms of tools, machinery, equipment, facilities, equipment, legislation related to aspects of occupational safety and security of quality food products.

For parameter sensitivity "socio territorial" means the ability of the territory surrounding the company, to absorb the impact that comes from. The macroindicatori identified were detected with regard to environmental safety, starting from Annex VI of the Rules and Emas are: energy resources, atmospheric emissions, waste, water cycle (water, waste water), noise, impact on infrastructure. Security and fire risk, interactions with the landscape, dangerous chemicals in the soil, into the raw materials and auxiliary.

The macroindicatori identified were detected, with regard to food safety, starting from the Italian Legislative Decree 1155/1997 are: analysis of hazards, sufficiency of resources, identification of security procedures, application, maintenance and updating of security procedures, tracing, structural prerequisites, prerequisite of plant and process, control of infestations, chemical / microbiological analysis, periodic training of personnel.

The macroindicatori identified were detected, with regard to job security on the basis of Italian Legislative Decree 626/1994 and subsequent amendments are: assessment of risks to health, assessment of risks to safety risks of fire and explosion and signs, incidental risks assessment, emergency management, prevention measures and collective protection,

information and training, Individual protection devices, health surveillance, documentation, monitoring.

At this point were calculated numerical values of three parameters A, B, C, for each aspect considered and for each sector (environmental, labor, food), as the arithmetic mean between the aggregated scores from individual applications. They then multiplied the values of the averages of three parameters, obtaining a numerical value between 1 and 64, where 1 is the score that expresses the worst situation and 64 is the best score or the score that indicates a good management by the dairy of environmental security, food and work. This type of scoring provides the first indications on the hierarchy of rational actions for the achievement and continuous improvement of security in the three areas under consideration. Within the scale of priority levels, was set a threshold beyond which analysed aspects should be considered significant, or halfway between 1 and 64 and then in need of urgent interventions, to distinguish them from those less significant that may be overlooked or not subject to immediate improvement.

The check-list were initially tested on a significant sample of 4 dairies and then applied to all companies under study. The figures were revised by spreadsheet, through which was created a matrix for processing statistics in order to identify the parameters of comparison of companies. The final results were displayed through appropriate graphics-type radar, which allow an immediate interpretation of the situation.

Results

The data collected through the checklist and use of radar graphs have permitted a rapid display of critical points present, which then can implement targeted interventions. The check-list on food safety has brought to light the problem of training of personnel (especially if casual) (Fig.1).

The need in some periods of casual labour when they are not always readily available, makes the choice to fall on those little specialized, often foreign and inexperienced. The brief time spent by workers on training and thereby to the detriment of food safety and workers' safety themselves.

Another critical point emerged in that of track and trace of the product. In some dairies traceability is achieved in a rudimentary way. It simply reports the date of packaging and expiry date of the product, which is not sufficient for the identification of the history of the product.

Other dairies, especially those medium-large, display traceability in a analytical manner, with technical personnel of the company and with the help of external consultants. It should however be noted that there is a process of adjustment in the procedure of traceability, which include the identification code of the product in transport documents.

With regard to HACCP, all dairies have been found adequate and are followed by external companies, which have fulfilled the conditions of manual. In general it was found that this is almost always the same consulting firm that follows and realizes for most dairies all the various plans and diagrams flow of production provided by HACCP.

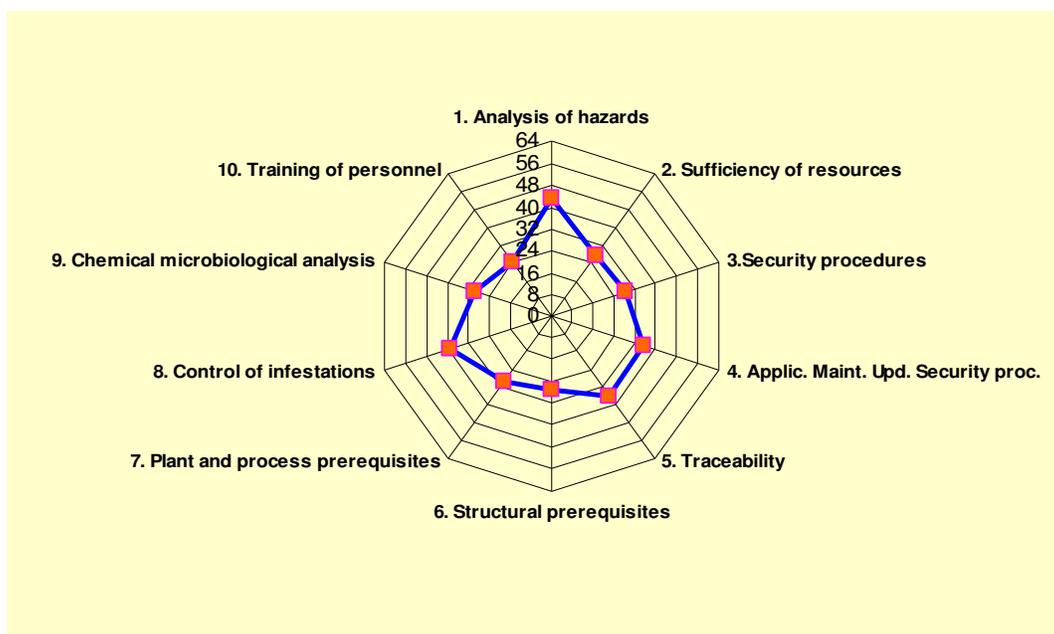


Figure 1. Food safety.

The same can be said regarding the workers' safety, followed by consultancy firm external to the company (Fig.2). With regard to this aspect the main problem was the noise, both external and internal. The main sources of emissions are the pasteurizer, in the boiler room and steam boilers double bottom.

In particular, the production plant steam develops high noise levels. This problem is obviously more important where the size of dairy production is greater. Unfortunately, P.P.E. (Personal Protection Equipments) only rarely are used.

There have been reports in which the external noise causes same troubles, so as to cause complaints by the neighbouring population. In general, in fact, in almost all the dairies subject to inspection has been found no zoning acoustics. However, keep in mind that, except for one case, the plants are located in agricultural or industrial zone, with few homes nearby.

The problem of waste is important, but it is almost always resolved in an appropriate manner (Fig.3).

With regard to this environmental aspect it is possible to make a distinction between large and small dairies. In fact, while the medium to large dairies operate separate collection for 5 types of waste (packaging, paper and paperboard, plastic, empty containers, mud residue processing) plus unsorted waste going to municipal bins, all other dairies operate undifferentiated disposal in bins without any management mode.

With regard to environmental security what emerges clearly is a general disinterest, a closure (except for two dairies respectively located in sites of significant environmental interest) to reliance on alternative energy sources (photovoltaic). They are to report also "Raw materials and auxiliary", not yet controlled by legislation, but still covered by EMAS Regulation.

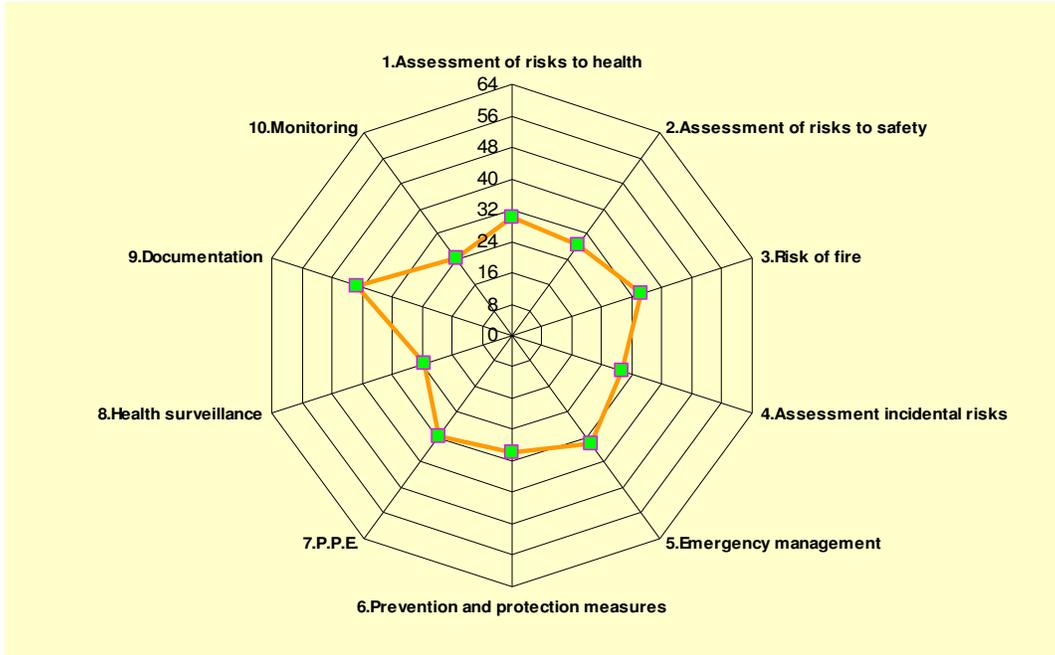


Figure 2. Workers' safety at work.

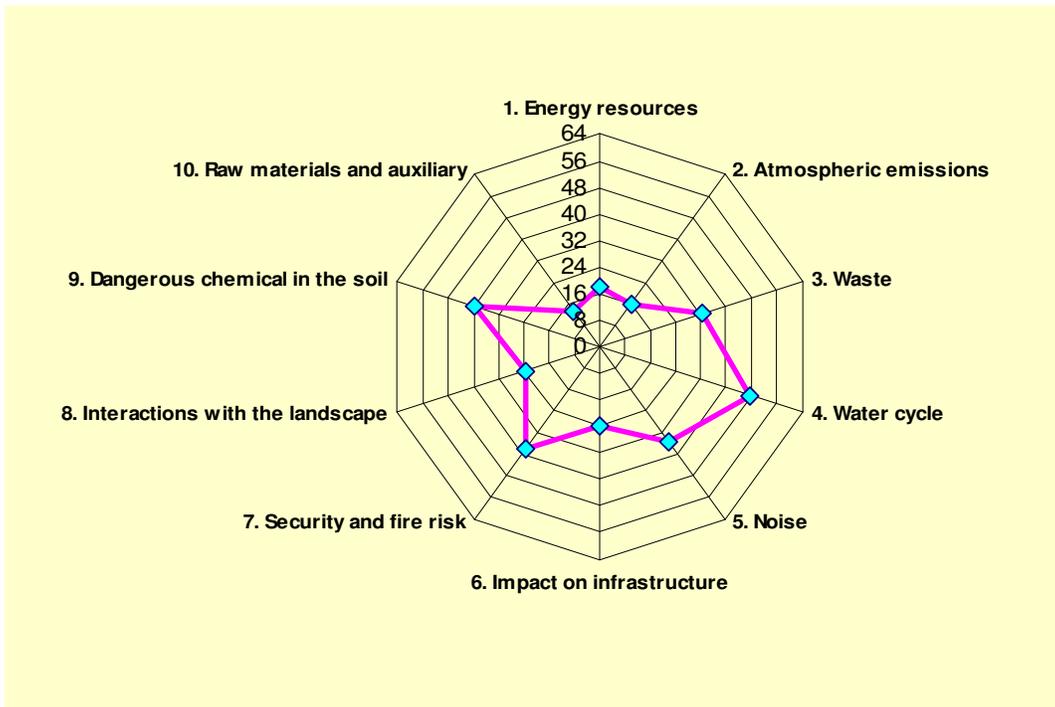


Figure 3. Environmental security.

Conclusions

The checklist gave an overview of security in the dairy sector in question. Moreover it is a tool for easy application and also able, with appropriate adaptations, to be used in other agro-industrial sectors.

Important is also the possibility, by the employer, to make a quick summary judgement on the conditions on his factory, even after ameliorative interventions have been adopted, to know their efficacy.

For every aspect taken into account several questions were raised, to which were given a different score, so the check-list provides implicit suggestions on how to improve the situation.

The marks awarded are surely the most subjective method, but beyond the numerical results, does not affect the meaning of the results themselves. In practice where there are problems are evident.

Acknowledgements

Research carried out with MIUR (Ministry of the University and Research) PRIN 2006-2007 funds, titled "Analysis of the applicability and extent of worker safety norms and of the quality and safety of food products: studies for some processing factories", national coordinator Prof. G. Zoppello.

References

Anderson V.P. 1988. Cumulative trauma disorders: a manual for musculo-skeletal diseases of the upper limb. Taylor and Francis.

Armstrong T.J., Ulin S. 1995. Analysis and design of jobs for control of work-related upper limb disorders. M.H. Hunter.

Colombini D., Occhipinti E., Grieco A. 2002. Risk assessment and management of repetitive movements and exertions of upper limbs: job analysis, OCRA risk index, prevention strategies and design principles. The Netherlands Elsevier.

Hagberg M., Silverstein B., Wells R. 1995. Work-related musculoskeletal disorders. A reference book for prevention. Taylor and Francis.

Monarca D., Porceddu P.R., Cecchini M., Babucci V. 2005. La valutazione del rischio da microclima negli ambienti di lavoro agroindustriali. *Rivista di Ingegneria Agraria*, 4, 89-93.

Porceddu P.R., Babucci V. 2005. Profili di rischio nei caseifici. Proceedings A.I.I.A. Italian Association of Agricultural Engineering L'ingegneria Agraria per lo Sviluppo Sostenibile dell'Area Mediterranea, Catania, Italy 27-30 June.

Porceddu P.R., Babucci V. 2007. Analysis of the main risk factors for workers' safety in some dairies. *Journal of Agricultural Engineering*, 3, 9-15.

Safety guidelines of the early phases of timber processing

Giametta G., Zimbalatti G., Proto A. R.

Dept. Agroforestry and Environmental Sciences and Technologies (DiSTaFA),

Mediterranean University of Reggio Calabria, Italy - Feo di Vito - 89122 Reggio Calabria

E-mail: gennaro.giametta@unirc.it; gzimbalatti@unirc.it; andrea.proto@unirc.it

Abstract

Over the last decade workers' health and safety have been given a growing attention and the laws issued in Italy to protect and improve both workers' health and work standards are intended to avoid, or at least contain, occupational hazards and diseases. Now, in view of the very important role of the timber sector within the Italian economy and particularly of the Calabria Region, and in consideration of the crucial issues linked to workplace safety in this same sector, it was decided to carry out a comprehensive assessment of the hazards related to timber processing in a sample of nine timber processing businesses. The main objectives of the study were: i) defining risk profiles in the sector under consideration, and ii) formulating technical proposals and fixes targeted to risk reduction. The study has in addition assessed both sanitation and environmental conditions for all the workers. The survey has highlighted a rather serious situation, in terms of work safety conditions, of the sector of timber processing. The results obtained do suggest that additional research efforts and targeted worker's training are required to improve safety conditions in timber processing businesses safety, in particular should become a sort of discipline in daily business operations.

Keywords: safety, timber processing.

Introduction

Over the last decade, workers' health and safety have been given a growing attention as shown by the laws passed by the Italian Government in this same period which are primarily intended to avoid – or at least contain – work hazards and disease. The data collected by the Agencies confirm that timber processing is an activity with high risk in terms of hazard occurrence (INAIL, Italian Workers' Compensation Authority, 2003). This is also ascribable to the fact that the production chain in question still includes many hand-made processing phases, which imply direct exposure of workers to work environment risk factors (equipment, machines and materials). This exposure results from a closer and more continuous contact with dangerous equipment compared to other sectors (Table 1). The aim of the present study has been to address the need to deal with issues related to the safety of the equipment used in primary timber processing, including the regulations presently in force in this sector, as well as the analysis of the risks related to this productive activity.

The study has been conducted in Calabria, one of the most important Italian regions in terms of timber production with an annual amount of processed timber of 828,395 m³, i.e. 9% of the national amount and 34% of the total amount of timber processed in southern Italy. As to the typology of wood products produced, Calabria is one of the largest producers of sawn timber, ply-wood, beams and poles (ISTAT, 2006). Given the great economic importance of the Calabria wood sector and in view of the problems related to the work conditions of this sector, it has been decided to start from the assessment of the risks (on the basis of the laws currently in force) correlated to the production processes carried out in nine sawmills considered to be a representative sample of the entire regional sector.

Timber processing encompasses a number of different kinds of processes which are almost always characterized by an elevated level of automation. In spite of this, many businesses, also because of the low added value of the finished product, still rely on obsolete equipment and machines which, while still keeping a pretty good level of productivity, are likely to create many problems and jeopardize both the safety and the health of the workers (Zimbalatti *et al.*, 2007).

Table 1. Activity sectors: occupational hazard

Sector of economic activity	Index of frequency (*)				
	Temporary disability	Permanent disability	Death rate	Total	Index number
Metal processing	65.79	2.47	0.08	68.34	191.2
Non-metallic minerals	63.86	2.64	0.12	66.61	186.4
Timber processing	58.51	4.13	0.06	62.70	175.4
Construction	54.43	4.10	0.19	58.72	164.3
Industry and Services (combined)	34.19	1.49	0.06	35.74	100.0

(*) Accidents indemnified per 1,000 covered by INAIL (Italian Workers' Compensation Authority)

Methodology

Starting from the provisions contained in the laws presently in force in this sector, the present study was meant to analyze the risks correlated to production operations in nine sawmills considered to be a reliable sample of the entire sector of the Calabria region. Risk assessment is the determination of quantitative or qualitative value of risk related to a concrete situation and a recognized threat. The primary goal of the research effort, has been that of identifying risk profiles to be used as a background for the detection of specific technical fixes, intended to reduce the risk assessed for each one of the operations to be carried out (guidelines). The assessment of risks, has been carried out relying on a semi-quantitative criterion given by multiplying hazard likelihood (**P**) by the severity of damage (**D**). These two parameters had previously been given a "subjective score" on an 1 to 4 scale (Novello M. and Dallasega F., 2003). Under this subjective score system, a score of 1 for the parameter "**hazard likelihood**" meant a rare event, whereas a score of 4 was associated to a very frequent event. As to the parameter "**severity of damage**", a score of 1 was associated to mild traumas, whereas a score of 4 was associated to serious injuries.

The extent of the risk of accident has therefore been assessed by the construction of the matrix of the products:

$$\text{Risk} = \mathbf{P} \times \mathbf{D}$$

The application of such a procedure has allowed to define 3 classes of risk: **mild**, **average**, **high** (Figure 1). Within this framework, both hazard risks and health risks were taken into consideration (*physical, chemical and biological agents, difficult working conditions, work organization*).

As to the assessment of the risks of exposure, the study has envisaged a specific survey sheet containing a specific checklist of checkpoints meant to collect three kinds of data:

- Description of the work (*hand-made, mechanized, etc.*);
- Detection of potential risks and resulting damage (*source and typology of risk, risk-damage correlation*);
- Risk assessment (*outcome of the survey in a scale of risk and priorities*).

Hazard Likelihood					
Highly Likely	4	4	8	12	16
Likely	3	3	6	9	12
Poorly Likely	2	2	4	6	8
Unlikely	1	1	2	3	4
Reference Scale	1 Mild	2 Medium	3 Serious	4 Very serious	Severity of Damage

Figure 1. Matrix for Risk Assessment (R = P x D)

The first phase of the work in question was meant to explore and learn the provisions contained in the laws presently in force on farm work safety. This made it possible to detect the specific risks of timber processing. In more detail, the above survey form was set up of each and any phase of the processing cycle and supply chain highlighting the peculiar nature of the operations carried out by operators (specific risk). In addition, the above operations were described synthetically to be ranked according to specific level of mechanization of each infield operation. The selection of the nine sawmills (designated by alphabet letters from A to I) deemed to be a representative sample for the present study, has been based on two parameters: i) their geographic location and ii) the different milling processes carried out within them (Warensjö M., 1997). Nevertheless the sawmills selected differed in terms of size, type of timber processed and of wood products, number of workers, productive processes and machines (Table 2). The study has in addition focused on both business management aspects and workers' behaviour during the different processing phases for which also the number of workers involved has been assessed. After analyzing the many cropping operations required in timber processing, some specific records were devised to indicate the appropriate safety measures for each cropping operation in a view to determining present risks, potential damage, safety guidelines and containment measures to prevent the risks assessed. The records for the assessment of specific risks were worked out for each operation in order to highlight all the details of the different phases (Clavel P., 2003).

Results

The sawmills under study had an average annual production of 2.560 m³ wood products. The timber usually process comes from the provincial area (68%), from the other provinces of the Calabria Region (20%), and from both national and international markets (12%). In particular, all sawmills studied use to buy long stems which are then cut in to sawlogs by means of cross-cutting. Softwood sawlogs have an average length of about 4 m, whereas

hardwood sawlogs are on average 3 m long. The wood products fall within three categories: carpentry and construction materials, semi-finished products to be additionally processed and products for packing and boxing (Zimbalatti *et al.*, 2005).

At the end of the surveying and data processing phase, 21 technical sheets have been drawn up which are intended to summarize the specific occupational risks observed and assessed as well as the guidelines to be followed to prevent, or at least contain, the risks of the individual processing phases. A synthesis of the main aspects highlighted in the different phases of processing is given below. For the sake of synthesis, the assessment of risk in "limit cases" observed has been prioritized disregarding low-profile risk situations (Table 3).

Table 2. Features of sawmills studied

	Number of workers	Timber volume (m ³ /year)	Species of wood	Products	Workforce (days/year)
A	5	900	Chestnut, beech, poplar	Carpentry and packing timber	210
B	9	4.000	Corsican pine, Silver fir	Trusses, semi-finished products	250
C	8	3.000	Chestnut, beech	Semi-finished and carpentry timber	245
D	6	1.100	Corsican pine, Silver fir	Carpentry timber	215
E	11	7.000	Chestnut, Silver fir	Semi-finished for furnishings, pallets, carpentry	275
F	7	2.600	Corsican pine, beech	Carpentry timber	230
G	8	2.000	Chestnut, Silver fir	Semi-finished for furnishings and standing finishes, pallets	220
H	6	700	Beech, Silver fir	Semi-finished for furnishings and standing finishes	205
I	7	1.800	Corsican pine, beech	Packing timber, pallets	225

a. Logs handling

Workers moving across the stacks of logs can happen to be accidentally in contact with log protruding parts; log moving machines can hit the workers in the log handling area. There is a high risk of fall and/or rolling down of the logs from atop stacks, which can be either ascribed to mistakes made by the drivers of the machines or result from load instability when piling up the logs. The assessment of the risks connected to these operations for the labourers under study, led us to define this risk as **likely** with a **mild** damage (R3.5: average). The guidelines proposed suggest a greater use of mechanical checks, as well as a constant use of PPE and of transit paths for clean enough operations.

b. Barking

The possibility does exist for workers to run into trunks in motion or in machine operating mechanisms due to either a poor keeping of the machines in question, or to the projection of splinters during barking operations. Noise and dusts are produced by the

operation of barkers, which "remove" the bark very rapidly by means of rotating blades and release elevated levels of dusts and noise "polluting" the area around. The hazard risk detected for the 67 labourers of the 9 sawmill under study involved in this phase can be defined as a **high** risk followed by a **mild** damage (R5.5: average). The guidelines formulated focus essentially on a high level of training of the labourers involved, accompanied by constant use of Personal Protective Equipment (PPE). Employers should in this case emphasize the importance of keeping a right posture during these operations, which should also be supplemented with compensation physical exercise, if needed.

c. Logs cutting

In addition to the above risks, which result from elevated levels of noise levels and dusts, also microclimate conditions are important for human health, especially in the sawing areas and when machine drivers are not protected by a cab. In this case the risk has to do with the uncomfortable temperatures that can be reached, especially in wintertime. Therefore risk containment measures adopted by the employer and implemented by the labourers are of crucial importance. This also highlights the importance of an efficient use of those devices meant to reduce at most exposure to wood dusts, noise and repeated movements. Such hazard risk, defined as **likely** with **medium** damage (R7: average-high)

d. Board cutting

In this case the possibility does exist to run into shearing or transmission mechanisms when processing is carried out in a wrong manner, during parts replacement or during machine keeping operations. Elevated levels of noise and of dusts are observed near the multi-blade saw which can result from i) boards hitting the working mechanisms, ii) machine engines, iii) boards jolting on the rollers of the conveyor belts; etc. The labourers of the sample under investigation were therefore observed to be exposed to this **highly likely** risk with a resulting **serious** or **very serious** damage (R9.5: high). The related damage (acute poisoning, asthma, nasal inflammation, hypoacusia, etc.) is not only due to an inappropriate use of the machine, but, and maybe more importantly, to a wrong state of repair of this device. Therefore employers should quantify the time of exposure of labourers to such risks and, if needed, to reduce exposure at most.

e. Chipping

As the chipping system is frequently found at the periphery of the sawmill, access to this area is often uncomfortable and poorly illuminated. Workers can therefore happen to bump into parts of the sawing system or find obstacles in their way, slide on wet ground and sawdust or have problems of any nature due to the lack of room and of light to handle fresh chips. The assessment of the risks connected to this operation in many labourers under study led us to define this risk as **likely** with a **medium** damage (R6: average). As is the case for other dangerous phases, the negative effects on health deriving from a wrong or inappropriate exposure can be summarized as follows: asthma, nasal inflammation, hypoacusia, discomfort, stress. Compensation physical exercise and correct use of PPE can reduce these risks.

f. Stacking and Carriage of finished product

Workers can happen to be hit by the protruding parts of the machines, by bundles or packs of boards stored in the different areas and, when walking in the area of the conveyor belts of the sawing machines, by moving boards. In addition, a poor illumination or an error in driving the handling machines, can result in a risk for the workers to run into fork lifts; the

risk also exists that boards fall from conveyors, from fork lifts or from "intermediate" deposit boxes due to the absence, inappropriateness and/or inadequacy of anti-fall devices. This exposes labourers to the risk of falls, slipping from the top of ladders as well as to ergonomically inappropriate movement repetitiveness. This risk was assessed to be **highly likely** with **mild** damage (R4.5: average). For this reason the containment measures reported in the table 3 can concern, say, the use of ladders prescribed by current regulations as well as the use of safety hooks and/or other devices and prohibition for more than one people to work on the same ladder and the use of specific PPE.

Table 3. Safety guidelines

Operation description	Risks detected	Expected damage	Risk assessment	Safety guidelines	Risk containment measures
<u>Logs handling</u>	Implement/device breakdown or out of control	Various injuries	R3.5: mild (likely with mild damage)	Training of labourers on appropriate working postures and conditions	Potential use of pruning devices
	Inappropriate posture				Compensation physical exercise
<u>Barking</u>	Inappropriate posture	Back-lumbar pain	R5.5: average (highly likely with mild damage)	Assessment of exposures	Appropriate clothing and safety shoes
	Wood Dusts Noise	Asthma, nasal inflammation, hypoacusia			Use of PPE
<u>Logs cutting</u>	Wood Dusts Noise	Asthma, nasal inflammation, stress, hypoacusia	R7: average-high (likely with medium damage)	Training of labourers on modalities to lift heavy loads and appropriate working postures	Use of law compliant equipment
	Being caught in moving parts, contact with parts during operation	Contact injuries Fatigue			Appropriate clothing and safety shoes
<u>Board cutting</u>	Cutting blades Inappropriate posture	Various injuries Back-lumbar pain	R9.5: high (highly likely with serious or very serious damage)	Assessment of exposures	Use of PPE
	Wood Dusts Noise	Asthma, discomfort, stress, hypoacusia			Compensation physical exercise
<u>Chipping</u>	Wood Dusts Noise	Asthma, nasal inflammation, hypoacusia	R6: average (likely with medium damage)	Assessment of exposures	Correct state of repair Use of PPE
<u>Stacking and carriage of finished product</u>	Inappropriate posture Hand lifting of heavy loads	Back-lumbar pain Elevated fall	R4.5: average (highly likely with mild damage)	Training of labourers on modalities to lift heavy loads and appropriate working postures	Potential use of pruning devices Compensation physical exercise

Conclusions

This study has enabled to widen our understanding of the general picture of the sector of primary timber processing, whose many criticalities in terms of work safety have not only been highlighted and observed, but also analysed. The guidelines worked out, are intended to contribute to improve the approach to problems related to the safety of the labourers of the timber processing sector on the basis of the relative risks assessed for each production phase together with resulting potential damage. The sector of primary timber processing in Calabria has been found to be characterized by extremely promiscuous tasks as well as by ill-designed and managed work premises and a lot of gaps in terms of compliance with safety and hygiene standards. On the grounds of the first results obtained, it seems evident that research and personnel training efforts are essential to improve safety conditions within wood processing businesses. This should be done in spite of the fact that the full regularization and compliance with work safety standards of these businesses, will take a lot of time not only for technical reasons but also, and may be more importantly, for the impossibility to adopt cost-efficient measures due to the fierce competitiveness of the sector in question, which is almost exclusively based on price policies.

References

Alwis K.U., Mandryk J., Hocking A.D., Lee J., Mayhew T., Baker W., 1999. Dust exposures in the wood processing industry. *American Industrial Hygiene Association Journal*, n°60, 641±646.

Clavel P., 2003. Risk assessment for agricultural machinery. XXX CIOSTA – CIGRV Congress Management and Technology applications to empower agriculture and agro-food system, Torino 22-24 settembre, 1118-1124.

IARC - International Agency for Research on Cancer. 1995. Overall Evaluations of Carcinogenicity to Humans: Wood dust and Formaldehyde. *Lione*, 9±215.

INAIL, 2003. Il fenomeno infortunistico nel 2003. Rapporto annuale.

ISTAT, 2005. Statistiche forestali. Roma.

Novello M., Dallasega F., 2003. Rischi e prevenzioni infortuni - Il caso dell'assestamento forestale. *Sherwood*, n°85, 35±40.

Warensjö M., 1997. The sawmill industry 1995, Part 1 and 2, Report 257. Department of Forest Products, Uppsala University.

Zimbalatti G., Giametta F., Proto A.R., 2007. Analysis of the risks of the early phases of timber processing. *Atti dell' International Agricultural Engineering Conference "Cutting edge technologies and innovations on sustainable resources for world food sufficiency"*, Bangkok, 3-6 dicembre.

Zimbalatti G., Proto A.R., Abenavoli L.M., 2005. Impianti e cicli produttivi in segherie calabresi. *Atti del Convegno AIIA "L'ingegneria agraria per lo sviluppo sostenibile dell'area mediterranea"*, Catania 27-30 giugno.

The authors participated equally in all the phases of the present work.

The definition of planning criteria for safe workplaces in wineries

Failla A., Tomaselli G., Strano L.
University of Catania. DIA, Costruction and Territory
Via Santa Sofia, 100 – 95123 Catania, ITALY.
Tel 0039 0957147573, Fax 0039 0957147600, gitomas@unict.it

Abstract

Surveys by the ISPESL [Higher Institute for the Prevention of Accidents and Security at Work] have highlighted numerous accidents at work in the wine industry related to building type and environmental conditions. To this end research was carried out in several wineries in Eastern Sicily. Analyses of the environmental, technological and organisational needs of work-spaces have produced the technical and functional characteristics of the pathways within and which link every work area. In relation to operative norms, it has been possible to identify design criteria to guarantee employee safety.

Keywords: work-place, safety, planning criteria, transit-way.

Introduction

ISPESL data for 2000 – 2006 highlights above average (650,000 annual) numbers of work related accidents particularly in the north and less so in Central and Southern Italy. The figures for Sicily are also on the rise with an annual average of 23,577 accidents. Palermo province has the highest number of registered accidents followed by the provinces of Catania, Messina, Ragusa, Trapani, Siracusa, Agrigento, Caltanissetta and Enna.

A detailed look at work-related accidents in Sicily from 2000 – 2006 for the Food Industry sector covering drinks and tobacco reveals 4,262 against 127,904 accidents nationally with an annual average of 609.

The category of 'Wine, Table Wine and Special Wine Production' registered 189 accidents against 3,887 nationally. The data raises several important issues which essentially lead to a growth in production which is not adequately proportional to aspects of structure, plant and organisation. Construction and organisational inefficiencies seem to involve all sectors of production since they correspond to large increase in work-related accidents notwithstanding the norms on safety.

The wine sector seems to be particularly hit by this problem. Wineries often have technical-structural characteristics which are not up to the work processes they wish to carry out (Cividino et al., 2005; Dioguardi, 2005). In particular, spaces, room sizes and their distribution, product and employee flow, are not very rational.

This is confirmed by ISPESL data on 'accident agents' for buildings and work areas. The greatest number of accidents in the category 'Wine, Table Wine and Special Wine Production' are: 435 cases of 'work surfaces and transit' (27 in Sicily); 120 cases of 'stairs and gangways' (4 in Sicily); then in descending order 'building features' and 'wall and floor openings' being the lowest of all for a total of 592 accidents. Closer analysis of 'accident agent', 'work surfaces and transit' and 'stairs and gangways' reveals that the main causes of risk are due to 'floors' and 'flights of steps and stairs' with 124 and 72 national accidents respectively.

This would lead one to believe that to date these problems have not been resolved. The lack of work safety is therefore due to breaching the law [D.Lgs. 626/94], the undervaluation of the risks or the lack of awareness of employees.

Another fundamental element worthy of consideration is the poor inspection of company safety systems (Safety Management Systems or UNI norms) which should be able to advise on product quality and safety by means of system management and improvement of the critical phases of production.

In wineries, work risk is above all due to vehicle transit during grape delivery and liquid transfer during control phases. Therefore it is indispensable there are 'safe work areas' designed to take into account employees' needs throughout the production phases and the inalienable hygiene requirements for food safety.

On the basis of the above, this study presents several Sicilian companies near Etna to identify the main risks involved with functional organisation and the environmental and construction characteristics of the transit-ways. Employee work activity was monitored and in particular the operations involving the transit of product or vehicles.

This winery research has led to criteria for design solutions which could help employees work in safety, taking into account the operative norms including D.Lgs. 81/2008 which substitutes D. Lgs. 629/94 regarding work-place safety.

Materials and methods

To identify work-place risk in wineries and suggest suitable design solutions, 5 wineries of different sizes were investigated which are noted in Eastern Sicily for the quality of their wines. The following company characteristics were noted: size (hectares cultivated), cultivar, workforce size, raw material transport, must in litres (daily average and maximum work capacity), bottled product (daily average and maximum work capacity), final product stock and waste disposal. For each work area in relation to the main means of transit, the transit-way characteristics considered to be fundamental for employee safety were analysed.

For each company, the data revealed refers to the following production areas: grape intake and pressing; fermentation; mellowing; bottling and storage. In each of these the following employee safety features were studied: work activity; transit routes: employees and/or vehicles; vehicle type; equipment and machinery; structural elements and functional surface features; signs and hazards. All the data has been reproduced in diagrams and graphs. Furthermore, taking into account employee work phases, the technical and functional characteristics of transit areas and the operative norms (D.Lgs. 81/2008, D.Lgs 493/96, DPR n. 547/55, ISO 22000:05) it was possible to identify certain design criteria for making transit 'safe'.

Results

Company analyses

By means of research into some venerable wineries in Eastern Sicily, those elements were identified which influence the planning of safe employee thoroughfares as regards, above all, environmental quality and the technological performance of floor systems, measurement and distribution of handling spaces in rapport with machinery and equipment.

Generally, the five companies have similar production characteristics both for the quantity of must and production in bottles (table 1). All the wineries use industrial technology given that the production phases are almost all mechanised. The number of employees is variable, increasing during the production season. The differences are essentially due to the distribution of handling spaces, the arrangement of machinery and equipment which is not₂

always compatible with production processes.

Table 1. Winery characteristics

Characteristics	Winery 1	Winery 2	Winery 3	Winery 4	Winery 5
Cultivar	- Nerello Mascalese	- Nero D'Avola - Frappato - Inzolia - Chardonnay	- Nero D'Avola - Nerello Mascalese - Inzolia - Chardonnay	- Caricante - Catarratto - Nerello Mascalese - Nerello Mantellato	- Nerello Mascalese
Cultivated hectares	17	32	32	25	19
Employees	5+seasonal	2+seasonal	2+seasonal	5+seasonal	2+seasonal
Raw materials transport	tractor +trailer	tractor +trailer	tractor +trailer	trailer	tractor +trailer
Average must L/day	3500	4600	4600	4500	3250
Must L/giorno (max production capacity)	4500	6000	6000	6000	4500
Average bottles/day	650	650	650	650	550
Bottles /day (max production capacity)	1400	1600	1600	1600	1000
Storage	12 bottle cases	6 bottle cases	6 bottle cases	6 bottle cases	6 bottle cases
Waste disposal	Distillery	Distillery	Distillery	Distillery	Distillery

The study has highlighted that safety requirements vary according to work spaces. In particular, the sections at highest risk are in 'grape pressing' and 'bottling/storage' since here there is the combined movement of several vehicles and employees.

In these areas, dangers emerge particularly when unloading raw materials because in most cases there is a drop between the truck height and the delivery level so employees risk falling down (wineries 2, 4 and 5)(fig. 1).

Furthermore, the bottling areas which ought to have their own space overlap with the storage area so the sizes of the vehicle lane and employee lane are insufficient to guarantee safe movement. By analysing employee flow it becomes apparent that it overlaps with vehicle flow (fig. 1).

Winery 2 suffers particularly from this overlap. The lack of space in the bottling area forces employees to use the 'mellowing' area as a temporary holding area for the latest consignments. However, the employees in both areas collude to make things work smoothly.

In all the wineries, employee and vehicle lane improvements have to be made especially in the initial and final phase areas of production.

By analysing the structural elements (fig. 2) the grape intake and pressing areas have earth, concrete or lava stone floors which are generally in good condition from a safety angle. Only in winery 4 are there some floor openings.

In the fermentation and mellowing areas risk is often determined by the inadequacy of space and its organisation considering all the vats present. In the fermentation area the main risk is from liquids on the floor making it slippery. Anti-slip solutions and sloping floors for better drainage are often insufficient. Most floors in this area are tiled (fig. 2). In the fermentation areas, restricted space and the use of stairs and gangways are the min elements affecting employee safety (wineries 1&5)(fig. 1).

The bottling department is one of the winery's areas at highest risk for employee safety. This is due to the machinery and work processes involved during which bottles may fall and break.

The risks are not only connected to moving machinery but also to liquids on the floor when the empty bottles are washed. Existing expedients often do not ensure the rapid total removal of liquids (fig. 2).



Figure 1. Diagrammatic plans of the wineries

	Winery 1	Winery 2	Winery 3	Winery 4	Winery 5
Intake and Pressing					
Earth floor	Present	Present	Present	Present	Present
Concrete floor	Present	Present	Present	Present	Present
Lava stone floor	Functional	Present	Present	Present	Present
Floor openings	Functional	Functional	Functional	Present	Present
Non-slip floor	Present	Present	Present	Present	Present
Sloping floor and drainage	Present	Present	Present	Present	Present
Stairs and catwalks	Present	Present	Present	Present	Present
Signs	Functional	Present	Present	Functional	Functional
Loading/Unloading ramps	Present	Present	Present	Present	Present
Lighting	Present	Present	Present	Present	Present
General surface condition	Functional	Functional	Functional	Non-Functional	Functional
Fermentation area					
Concrete floor	Present	Present	Present	Present	Present
Tiled floor	Present	Present	Present	Present	Present
Floor openings	Functional	Present	Functional	Functional	Functional
Non-slip floor	Present	Present	Present	Present	Present
Sloping floor and drainage	Present	Present	Present	Present	Present
Stairs and catwalks	Present	Present	Present	Present	Present
Signs	Functional	Present	Present	Present	Functional
Lighting	Present	Present	Present	Present	Present
General surface condition	Non-Functional	Non-Functional	Functional	Functional	Non-Functional
Mellowing area					
Concrete floor	Present	Present	Present	Present	Present
Terra cotta or lava tiles floor	Present	Present	Present	Present	Present
Tiled floor	Present	Present	Present	Present	Present
Floor openings	Functional	Present	Present	Functional	Functional
Non-slip floor	Present	Present	Present	Present	Present
Sloping floor and drainage	Present	Present	Present	Present	Present
Stairs and catwalks	Present	Present	Present	Present	Present
Signs	Functional	Functional	Functional	Present	Functional
Lighting	Present	Present	Present	Present	Present
General surface condition	Non-Functional	Functional	Functional	Functional	Functional
Bottling and Storage area					
Concrete floor	Present	Present	Present	Present	Present
Tiled floor	Present	Present	Present	Present	Present
Cement and resin floor	Present	Present	Present	Present	Present
Floor openings	Functional	Present	Functional	Functional	Functional
Non-slip floor	Present	Present	Present	Present	Present
Sloping floor and drainage	Present	Present	Present	Present	Present
Stairs and catwalks	Present	Present	Present	Present	Present
Signs	Functional	Functional	Present	Present	Functional
Lighting	Present	Present	Present	Present	Present
General surface condition	Non-Functional	Non-Functional	Non-Functional	Functional	Functional

Figure 2. Survey of building features regarding safety

lanes were in focus for the fermentation and mellowing areas.

Furthermore, for every area tables 3a and 3b show summaries of the safety norms and planning directions for lanes as they pertain to the following environmental and technological parameters: measurements, floors, signs, lighting and machinery.

Intake and Pressing

The intake and pressing areas should be large enough to cope with all the jobs of the special equipment needed and with the production capacity of the winery. For greater safety and functionality of the area, the machinery should be placed in 'cascade' providing a work scheme in hierarchical order. Any moving machinery at intake should not compromise the safety of any employees. There should be sufficient room for vehicle manoeuvre which is directly proportional to the size and turning circles of the trucks. From an environmental point of view, the intake area should protect employees from the weather and so the operating zone should have canopies as per the norms for work-place safety.

Planning criteria for lanes

The analysis and correlation of work processes together with the planning directions provided by other studies (Bonomo, 1999) regarding the environmental, organisational and technological characteristics in rapport with machinery, plant and safety provided definitions of some design criteria for lanes which can be taken as references when renovating wineries or planning new ones.

From a survey of the wineries the intake, pressing, bottling and storage departments are at highest risk as regards mechanised lanes, whereas the in the fermentation and mellowing departments the only risks are from pedestrian movement.

The following proposed criteria take into account the safety requirements during the periods of most activity when there are most vehicles in use, the space and structural requirements of the work areas, the transit of both employees and vehicles and even the health, protection and safety characteristics of the employees.

These criteria were defined for both the pedestrian and vehicular lanes in the areas of intake, pressing, bottling and storage, whereas only the pedestrian

Departments	Planning criteria for vehicular lanes	
	Norms	Parameters
Intake and Pressing	D.Lgs. 81/08 Titolo II e III; DPR 547/55 Art. 8 comma 3 e 4, Art.11; ISO 22000:05	Measurements Vehicular lanes: width should guarantee transit and manoeuvring. Lanes should be linear and not cross pedestrian lanes
	D.Lgs. 81/08 Titolo II; DPR 547/55 Art. 8 comma 9 e 10, Art.10 comma 1, Art. 11; ISO 22000:05	Flooring Durability should be adequate to use. Any floor openings should be covered seamlessly and well-marked. Should be dustless
	D.Lgs. 81/08 Titolo V; DPR 547/55 Art. 8 comma 5, 8 e 11, Art. 13, Art. 33; D.Lgs 493/96 Allegato V comma 1 e 2.	Signs Floor lane markings; 'pedestrians'; 'noise'; 'fire prevention'
	D.Lgs. 81/08 Titolo III capo III; DPR 547/55 Art. 28, Art. 29, Art. 30, Art. 31; Codice Civile Art. 2087 ; Legge 864/70 Art. 9; D.M. 26/08/92 Art. 7.1 lettera a)	Lighting Optimum lighting with artificial back-up in windowless areas; artificial lighting in outdoor work areas should night work take place
	D. Lgs 81/08 Titolo III capo III; ISO 22000:05	Plant engineering Plumbing for washing down all surface; good drainage for waste liquids; electricity installation
Bottling and Storage	D.Lgs. 81/08 Titolo II e III; DPR 547/55 Art. 8 comma 3 e 4, Art. 11; ISO 22000:05	Measurements Vehicular lanes: width should guarantee transit and manoeuvring. Lanes should be linear and not cross pedestrian lanes
	D.Lgs. 81/08 Titolo II; DPR 547/55 Art. 8 comma 9 e 10, Art.10 comma 1, Art. 11; ISO 22000:05	Flooring Durability should be adequate to use. Any floor openings should be covered seamlessly and well-marked. Should be dustless. Non-slip and washable surface
	D.Lgs. 81/08 Titolo V; DPR 547/55 Art. 8 comma 5,8 e11, Art. 13, Art. 33; D.Lgs 493/96 Allegato V comma 1 e 2.	Signs Floor lane markings; 'pedestrians'; 'nois'; 'fire prevention'
	D.Lgs. 81/08 Titolo III capo III; DPR 547/55 Art. 28, Art. 29, Art. 30, Art. 31; Art. 2087 Codice Civile; Legge 864/70 Art. 9; D.M. 26/08/92 Art. 7.1 lettera a)	Lighting Optimum lighting with artificial back-up
	D. Lgs. 81/08 Titolo III capo III; ISO 22000:05	Plant engineering Plumbing for washing down all surface; good drainage for waste liquids; electricity installation

Figure 3a. Summary of planning criteria and safety requirements for vehicular lanes

The durability of the floors should correspond to the physical-mechanical loads undertaken: high static and dynamic loads due to storage and vehicular transit. For the most part, floors are made of a bitumen mix or concrete; both are highly mechanically resistant and waterproof.

Stone slabs can also be used providing their thickness corresponds to the mechanical resistance they will be subjected to. Floors should also be non-slip, so they should incline to guarantee rapid drainage of wash water and rain water via drains and run-offs.

The intake area should directly connect with the pressing area to enable easy access for employees and product. The pressing machinery should be separate from service corridors which should allow inspection and operator control and the floors, apart from the above characteristics, should be able to remain hygienic.

Fermentation and mellowing

Wine vats should be in ordered lines with service corridors between which are wide enough for employee use. Vats should be at least 40 cm from the walls to accommodate cleaners and inspection. They should also be interspaced to allow lateral inspection. When the vats are very tall they need to be inspected from above so scaffolding and catwalks need to be provided. To guarantee employee safety and referring to current norms (D.Lgs. 81/2008), the catwalks should have non-slip surfaces and be protected by normal parapets with footguards or similar.

Departments	Planning criteria for pedestrian lanes	
	Norms	Parameters
Intake and Pressing	D.Lgs. 81/08 Titolo II e III; DPR 547/55 Art. 8 comma 1 e 2, Art. 11, Art. 15, Art. 16, Art. 27; ISO 22000:05	Measurements Pedestrian lanes: width should guarantee transit safety above all near machinery. Lanes should be linear and not cross vehicular lanes. Lanes close to variations in level should have railings. Holding lanes: work space must guarantee safety during plant inspection and maintenance
	D.Lgs. 81/08 titolo II; DPR 547/55 Art. 8 comma 9 e 10, Art. 10 comma 1, Art. 11; ISO 22000:05	Flooring Durability should be adequate to use. Any floor openings should be covered seamlessly and well-marked. Should be dustless
	D.Lgs. 81/08 Titolo V; DPR 547/55 Art. 8 comma 5, 8 e 11, Art. 13, Art. 33; D.Lgs 493/96 Allegato V comma 1 e 2.	Signs Floor lane markings; 'pedestrians'; 'noise'; 'fire prevention'; 'plant control panel'
	D.Lgs. 81/08 Titolo III capo III; DPR 547/55 Art 11 comma 6; Art. 2087 Codice Civile; Legge 864/70 Art. 9; D.M. 26/08/92 Art. 7.1 lettera a)	Lighting Optimum lighting with artificial back-up in windowless areas; artificial lighting in outdoor work areas should night work take place
	D. Lgs. 81/08 Titolo III capo III; ISO 22000:05	Plant engineering Plumbing for washing down all surface; good drainage for waste liquids; electricity installation
Fermentation and Mellowing	D.Lgs. 81/08 Titolo II e III; DPR 547/55 Art. 8 comma 1 e 2, Art. 11, Art. 15, Art. 16, Art. 27; ISO 22000:05	Measurements Pedestrian lanes: width should guarantee transit safety above all near machinery. Lanes should be linear and not cross vehicular lanes. Lanes close to variations in level should have railings and footguards. Holding lanes: work space must guarantee safety during plant inspection and maintenance
	D.Lgs. 81/08 Titolo II; DPR 547/55 Art. 8 comma 9 e 10, Art.10 comma 1, Art. 11; ISO 22000:05	Flooring Durability should be adequate to use. Any floor openings should be covered seamlessly and well-marked. There should be no obstacles or unevenness
	D.Lgs. 81/08 Titolo V; DPR 547/55 Art. 8 comma 5, 8 e 11, Art. 13, Art. 33; D.Lgs 493/96 Allegato V comma 1 e 2.	Signs 'Moving vehicles'; 'plant control panel'; 'fire prevention'
	D.Lgs. 81/08 Titolo III capo III; DPR 547/55 Art. 28, Art. 29, Art. 30, Art. 31; Codice Civile Art. 2087; Legge 864/70 Art. 9; D.M. 26/08/92 Art. 7.1 lettera a)	Lighting According to work need with artificial back-up
	D. Lgs. 81/08 Titolo III capo III; ISO 22000:05	Plant engineering Plumbing for washing down all surface; good drainage for waste liquids; electricity installation
Bottling and Storage	D.Lgs. 81/08 Titolo II e III; DPR 547/55 Art. 8 comma 1 e 2, Art. 11, Art. 15, Art. 16, Art. 27; ISO 22000:05	Measurements Pedestrian lanes: width should guarantee transit safety above all near machinery. Lanes should be linear and not cross vehicular lanes. Holding lanes: work space must guarantee safety during plant inspection and maintenance
	D.Lgs. 81/08 Titolo II; DPR 547/55 Art. 8 comma 9 e 10, Art.10 comma 1, Art. 11; ISO 22000:05	Flooring Durability should be adequate to use. Any floor openings should be covered seamlessly and well-marked. There should be no obstacles or unevenness
	D.Lgs. 81/08 Titolo V; DPR 547/55 Art. 8 comma 5, 8 e 11, Art. 13, Art. 33; D.Lgs 493/96 Allegato V comma 1 e 2.	Signs Floor lane markings; 'moving vehicles'; 'noise'; 'fire prevention'; 'plant control panel'
	D.Lgs. 81/08 Titolo III capo III; DPR 547/55 Art. 28, Art. 29, Art. 30, Art. 31; Codice Civile Art. 2087; Legge 864/70 Art. 9; D.M. 26/08/92 Art. 7.1 lettera a)	Lighting Optimum lighting and if necessary to include spot lighting above the bottling lines
	D. Lgs. 81/08 Titolo III capo III; ISO 22000:05	Plant engineering Plumbing for washing down all surface; good drainage for waste liquids; electricity installation

Figure 3b. Summary of the planning criteria and safety requirements for pedestrian lanes

Other aspects to be considered are the floor finishes which should be washable (also by law). They should be highly mechanically resistant especially since they are in contact with chemically aggressive liquids (must, wine and wash water). Today, the building materials industry have a variety of solutions with clinker tiles and other ceramic tiles. Resin claddings can also be easily applied to a concrete base producing viable flooring.

Bottling and Storage

The bottling department is one of the highest risk areas for employees. This is due to the type of machinery used during which work processes bottles can break compromising employee safety. Respecting the safety conditions laid down by the norms (D.Lgs.

81/2008) requires each machine be shielded; this means protective barriers which separate the operative areas of the machinery from those of the employees who, at this point in the production process, do little more than check the machines. In the bottling lines wherever employees are needed, raised shields are likewise needed to prevent direct contact with liquids.

The bottling phase inevitably leads to a large quantity of liquid on the floor which must be removed rapidly usually by means of a sloping floor with appropriately-sized run-offs and drains. The drains and channels need to be covered to maintain a seamless floor.

The choice of surface finishes must allow for washing and must resist acid corrosion (acetic acid, cleaning solutions); the floors should also be non-slip to safeguard employees since liquids are ever-present. For storage, the production and norm requirements are volumetric and must facilitate the rational organisation of loading and unloading so the vehicle manoeuvring area needs to be defined.

Conclusions

In this work, the main work processes involved in quality wineries located in Sicily have been analysed. This has led to specific criteria for planning transit areas, both for employees and vehicles, which answer the work-place safety requirements laid down by law. In particular, the resulting indications could contribute to construction and organisational precautions to limit work-place safety risks which arise during the more intricate production phases. Activating such measures, apart from answering safety and hygiene requirements, could reflect very positively on productivity and company management as regards:

- work organisation and productivity (checking production processes, data collection, optimum resource use, reduction of production times, etc.);
- plant efficiency, machinery and equipment (maintenance and correct use, energy saving, damage risk reduction);
- work quality (less fatigue, better hygiene, easier workforce availability);
- construction quality (reduction of covered areas, construction appropriateness);
- architectural quality (planning for maximum practicality, balanced use of space).

References

- Bonomo G. 1999. Definizione di linee metodologiche e criteri innovativi per la progettazione dei fabbricati dell'industria vinicola. Tesi per il conseguimento del titolo di Dottore di Ricerca in "Costruzioni agricole ed assetto del territorio, XII ciclo. Università degli studi di Reggio Calabria.
- Cividino S.R.S., Gubiani R., Zoppello G., Zucchiatti N. 2005. La sicurezza nelle cantine: situazione in Friuli Venezia Giulia. VIII Convegno Nazionale di Ingegneria Agraria, Catania, 27 – 30 giugno 2005.
- Cividino S.R.S., Gubiani R., Zoppello G. 2005. La progettazione delle cantine in un'ottica di sicurezza ed ergonomia. VIII Convegno Nazionale di Ingegneria Agraria, Catania, 27 – 30 giugno 2005.
- Dioguardi L. 2005. La progettazione integrata applicata a tre cantine del nord Italia. VIII Convegno Nazionale di Ingegneria Agraria, Catania, 27 – 30 giugno 2005.
- Failla A., Strano L., Tomaselli G. 2006. Innovative Building Design Criteria for the Confectionary Industry. CIGR Ejournal. Invited Overview, 12:1-26.

Hygienic and safety guidelines for the design of small-scale sausage factories

Denti M.¹, Pisanu M.¹, Usai E.¹, Checchi A.², Casazza S.²

¹*Dipartimento di Ingegneria del Territorio - Università di Sassari – Via De Nicola, 2, 07100 Sassari. Tel. +39 079 229242. e-mail: denti@uniss.it*

²*Dipartimento di Economia e Ingegneria Agraria - Università di Bologna- Via G. Fanin,50, 40127 Bologna. Tel. +39 051 20 9 6197. e-mail: achechchi@agrsci.unibo.it*

Abstract

The aim of this report is to produce guidelines for the design and construction of buildings and facilities used for small-scale traditional sausage factories, in order to combine maximum efficiency with code requirements for food handling (Italian Legislative Decree no. 155 of 26 May 1997) and work environment safety (Italian Legislative Decree no. 626 of 19 September 1994).

Said goal is achieved by means of a complex planning procedure (integrated design) based on a preliminary study of the manufacturing process. Integrated design is the basic plan for finding, describing and arranging the different functional areas (functional design), which is then combined with the requirements for food handling (HACCP rules) and job environment safety (Italian Legislative Decree 626/64 and more recent related laws), in order to obtain a complete and broad estimate of all risks connected with sanitation and safety in a sausage factory (global safety design). This is particularly important in a workplace where sharp tools are used and product aging in a healthy environment is a key factor.

The complete estimate of risks can be attained by developing the following procedures:

- 1) find risk sources in the manufacturing process;
- 2) identify what kind of risk is related to the specific activity;
- 3) evaluate the magnitude of each risk factor;
- 4) find planning solutions to alleviate and/or eliminate risks.

It is important to highlight that a building designed as a manufacturing facility has more reason to exist than just a domestic environment with machines, since it is actually an innovative container of advanced technology and an important factor in itself in the manufacturing process, which has to be performed in a functional, managerial manner, as well as in a safe and healthy environment.

Keywords: design, safety, sausage factories.

The method

The planning of a complete safety system in a building for the production of sausages must take place following a rigid protocol which, starting from a careful study of the factors that determine its economic feasibility, proceeds to an analysis of the context in which the factory is to be included so that it can fit in as closely as possible with the types of buildings in the area. Then viability, the distance of the plant from centres of distribution and its accessibility, must be studied.

Only after this can we go on to the analysis of the different stages in the work cycle so as to verify the presence and impacts of risks to the hygiene of products or that of workers. In this context it is necessary to proceed to the division of the processing cycle into functional

and rational stages, being careful not to superimpose operations having different hygienic impacts and thus avoiding dangerous cross-contamination.

In particular it is first of all necessary to take into account the aspects connected with "traditional" planning which are in detail:

1. **Functional aspects:** organization of the production cycle, definition of functional areas, study of flows and volumes;
2. **Building aspects:** connected with building characteristics. They concern the choice of the kind of foundation, load-bearing structures, outside walls and partitions, flooring, roofing, electric and hydraulic plants;
3. **Economic aspects:** these are closely connected with the previous aspects. The correct connection of the productive stages and the rational choice of materials and exposure may influence this point to a high degree. They represent, among other things, the basis for decision-making in project feasibility.
4. **Environmental aspects:** these concern most of all the control of factors such as temperature, relative humidity, luminosity, air flow and speed and so on.
5. **Dimensional aspects:** these are to be considered in an integrated approach to the project that takes into account both the peculiarities already described in the functional plan and the characteristics required by European and local legislation.

Finally, solutions must be found to bring traditional planning aspects into line with regulations now in force concerning product quality and safety in the workplace. The latter aspects, which represent the preponderant part of this study, will be dealt with in detail:

Cold cycle: cold storage room – salting room – maturing room – packaging-cold cycle.

"Technical processing": handling trolley – washing – larding – washing–washing water.

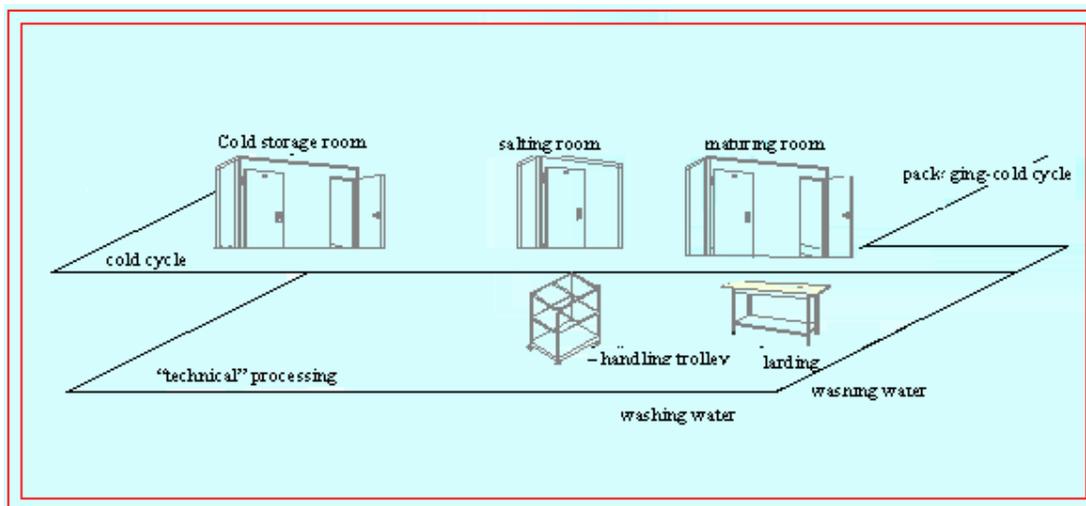


Figure 1 - Graphic representation of the work cycle for the production of hams.

Hygienic engineering

Community Directive n. 852 and follows related laws /EU "Hygiene of food products", adopted in Italy, establishes the obligation to set up a plan for hygienic controls over and safety of foodstuffs produced in processing plants. The directive imposes on companies in the food sector the putting into practice of control procedures based on the HACCP (Hazard Analysis Critical Control Point) methodology for the identification of potential dangers, the

evaluation of their seriousness, the probability of their occurrence and the application of control procedures.

In detail, it is necessary to see if the building designed on the basis of traditional planning methods is compatible with the need to maintain hygienic standards through control over hygienic "pollutants" which also in the case of meat processing structures may be:

- biological (presence of rodents, insects, mould, bacteria and so on),
- chemical (residues of detergents, spices gone bad and so on),
- physical (temperature, relative humidity and so on),

Contamination of foodstuffs may occur at any time during production and is influenced by the hygienic conditions in which they are prepared. Contamination is possible during the butchering stage, processing, conservation and marketing. In reality, if the animals are healthy and butchered following good hygienic practices, the danger of contamination is usually modest, with values between 102 and 104 UFC/cm².

It is good practice to try to avoid or at least limit possible contamination starting from the design stage by adopting suitable building solutions to ensure that the rooms are in the best condition to facilitate the necessary cleaning and disinfecting operations, using appropriate barriers to avoid the introduction of foreign elements (insects, animals). In general, building operations aimed at eliminating or attenuating the risks that emerge from the study of processing operations concern the choice of materials, (floors and wall linings that are easy to wash and disinfect and/or are insulated), of construction details (corners rounded off, sloping floors), furnishings (made of materials that are easy to wash and disinfect) and plants (lighting, ventilation, waste disposal and so on).

The study of the production process has led to the identification of the following critical points of danger of contamination (CP) and the relative remedies to eliminate or attenuate hygienic risks:

Risk	Remedies
CP1) stage of delivery of raw materials:	
Serious risk of contaminating meat since this area is in direct contact with the outside environment	Doors and windows that shut automatically and made with materials that are easy to wash and disinfect
CP2) processing stage:	
Improper sterilization of machinery and/or cutting tools. Dirty floors and walls	Floors and wall linings that are easy to wash and disinfect, floors sloping to drains and collection basins. Rounded-off corners to facilitate cleaning operations
CP3) 1st storage stage	
The products maturing in cold and drying cells lose too much liquid. They may bring in foreign matter from the outside	Ventilation systems with anti-bacteria filters. Control of temperature and humidity
CP2) finishing stage:	
Very limited dangers caused mostly by operators' carelessness or the poor quality of salt or, finally, the poor hygienic standards of the wood used in the smoking stage.	Proper choice of material without mould for use in smoking rooms. Certified salt
CP2) conservation stage:	

Very limited dangers since in this stage products are fairly well stabilized. Possible alterations may be caused by unsuitable temperature and humidity conditions.	Control of temperature and humidity.
CP6) cleaning and disinfection of the building:	
High risk caused by the presence of residues of detergents used in cleaning up.	Use of certified deteratives

Table 1. Critical points and possible solutions in the production of sausages.

Safety engineering

Proper safety engineering starts from a first systematic examination of previous engineering aspects so as to arrive at a "risk evaluation" for each functional stage. In detail, this is reached through the examination of the following elements:

- 1) identification of the sources of danger present in the work cycle;
- 2) identification of the consequent potential risks of exposure during processing;
- 3) estimate of the degree of exposure risks.

The actual engineering stage includes examination of the parts of the building that may create dangerous situations for workers. Generally speaking, in food processing structures such elements are connected with the following risk factors:

a) factors inherent in plants

- 1) **use of machinery and plants:** In the building considered many machines are necessary in the work cycle.
- 2) **presence of electrical equipment:** Workers are particularly aware of risks connected with the use of electrical equipment which are electric shock, burns and fires caused by short circuits in environments characterized by the presence of spilt liquids on the floor or water used in cleaning operations.
- 3) **fire risk in smoking rooms:** Risk of fire caused by uncontrolled combustion of the aromatized sawdust used in smoking sausages. Possible accidental combustion of the stored material. For safety measures, see the paragraph on calculation of fire load.
- 4) **exposure to noise:** The noise level in a sausage factory is fairly limited, but in some areas there are machines operating at the same time (air compressors, pumps, various automatic devices) that cause higher noise levels. In any case, workers must be given detailed instructions concerning the risk of noise together with information on the proper use of individual protective devices (IPD) that contribute to limiting possible damage.
- 5) **handling of heavy loads (sides of animals, cuts of meat and so on).** The handling of sides of butchered animals and the products of sausage factories takes place with the use of automated conveyors. Therefore, risks in the areas where they are handled can be considered negligible. But in the area of delivery of the finished products the situation is different owing to the use of fork lifts or hand pallet trucks. These activities represent a fairly high source of risk: fork lifts must have a driver's seat protected against the fall of objects from above, an acoustic signal and a flashing yellow light and must have a load-locking device in case of breakdowns during load lifting or lowering operations. Transport must take place with the fork at its lowest point and raising and lowering operations are to be performed with the truck braked. In the case of manual handling of heavy loads, workers must use all possible precautions to avoid back injuries. Such precautions are often dictated more by common sense than by specific training on the subject.

b) factors connected with buildings and construction techniques

- 1) **electric plant:** The risks connected with the presence of electricity are those mentioned in point 2A) above and concern possible electric shocks and burns to workers and the risk of fire in the case of overloads. The main preventive measures are those described in safety legislation concerning electric plants (Law no. 186/68 - Presidential Decree 547/55) and must be properly designed and include an efficient earthing system, sectioning of lines, the use of conductors of suitable diameter and differential thermal circuit breakers. Owing to the large amounts of water used in sausage factories, they are undoubtedly damp work places; thus the electric plant must be installed using waterproof control panels and sockets.
- 2) **lack of signals for grates, wells, sinks and trap doors;** These building elements should not be used. In any case, they must be clearly marked with specific signs and the use of highly visible paints (diagonal yellow and black stripes and so on).
- 3) **stairs, walkways, floors and slippery pavements;** these elements are all possible causes of falls by workers since liquids and slippery substances may accidentally accumulate on them. The simplest solution is the use of rough surfaces which greatly decrease the risk of dangerous falls. Also in this case information is fundamental in reducing the risk just as is the obligation to supply workers with safety shoes with non-slip soles. Floors must be laid with slopes usually between 1.5 and 2% so as to drain excess water quickly.
- 4) **absence or insufficiency of escape and emergency routes;** these are to be considered a source of risk if they are not located in the right place and are too narrow. They must be kept free of obstacles, well marked and easy to reach following luminous signs that go on automatically when the mains go off. In detail, emergency exits must be at least two metres high with doors opening outwards with anti-panic door handles. Sliding doors and shutters are not admitted when there are no doors opening outwards.
- 5) **absent or insufficient signs:** To complete the picture concerning the prevention of possible accidents, a fundamental role is played by warning signals and signs. Signs are immediate instruments for identifying sources of dangers and supplying useful information on how to avoid them. Signs must be placed where they are perfectly visible and must receive the necessary attention.
- 6) **absence of calculation of the fire load in defining the dimension and characteristics of fire-fighting equipment;** the legislation now in force is quite strict and imposes a series of measures for fire prevention and fighting. Reference is made to Presidential Decree no. 577 of 29 July 1982 which disciplines fire prevention to safeguard human life and protect property and the environment. The design must be approved by officials of the Fire Brigade and must cover the following points:
 - condition and amount of insulation;
 - fire resistance of structures;
 - vertical and horizontal compartmentalization;
 - possibility of evacuating combustion gases;
 - available water resources;
 - possibility of access by rescue vehicles;
 - suitable number of easily reachable exits. Activities cannot be carried on until the Fire Prevention Certificate has been issued following an inspection by the Fire Brigade.

Calculation of the building's class of resistance to fire is the central issue in the design and is performed with the formula:

$$C = K \cdot q$$

where:

C = building class

q = fire load

K = reduction coefficient

Determination of these parameters establishes for how long the building is capable of resisting fire. The Fire Prevention Certificate also includes the different measures for the prevention of fires and the plants and equipment that the building must contain for the control and prevention of fires.

Among these measures we must consider the installation of a fire-fighting plant that takes the necessary water from a special reservoir, which in our case may be the emergency reservoir. Also required is the presence of a suitable number of extinguishers (defined in the FPC) that are clearly marked, easy to reach and constantly checked to make sure they work properly.

There must also be emergency exits, they too dependent on the building's class of resistance to fire, of suitable size, easy to reach and well marked at every point in the building. The fire prevention plant is to be completed with signs and information for workers to be supplied by the safety officer concerning the operations to be performed in case of fire.

Regulations call for the creation of a protected route that offers suitable protection against the effects of fire. It must guarantee evacuation of the building towards safe places in the shortest possible time, it must contain no obstacles and must have escape routes with emergency exits. Evacuation times and the distance between emergency exits are a function of the building's fire risk:

- 15 ÷ 30 metres (max. evacuation time 1 minute) for areas with a high risk of fire;
- 30 ÷ 45 metres (max. evacuation time 3 minutes) for areas with a medium risk of fire;
- 45 ÷ 60 metres (max. evacuation time 5 minutes) for areas with a low risk of fire;

Single emergency routes must be avoided as much as possible. When they cannot be avoided, the distance to an emergency exit or to the point where two or more emergency routes become available should not exceed the following values:

- 6 ÷ 15 metres (max. travel time 30 seconds) for areas with a high risk of fire;
- 9 ÷ 30 metres (max. travel time 1 minute) for areas with a medium risk of fire;
- 12 ÷ 45 metres (max. travel time 3 minutes) for areas with a low risk of fire;

Emergency routes must be sufficiently wide to accommodate the number of persons working in the building: the width is to be measured at the narrowest point. Every door along the route must be easy to open for the persons seeking their way out.

For places with a medium or low fire risk, the overall width of exits per floor must not be less than:

$$L \text{ (metres)} = A/50 \times 0.60$$

where "A" represents the number of persons present on the floor (crowding); the value 0.60 is the width (in metres) sufficient for the transit of one person (single passage module); 50 is the maximum number of persons that can leave through a single passage module, taking into account evacuation time.

c) *factors connected with the processing cycle*

- 1) **potentially dangerous chemicals:** particularly aggressive deteratives;
- 2) **personal protective equipment:** in sausage factories personal protective equipment is of great importance owing to the frequent use of sharp tools and meat grinders. Operators must be equipped with special steel-mesh gloves, possibly with rigid steel mesh covering the forearm. Also available on the market are protective aprons made of aluminium, especially useful in sectioning operations, and other rubber aprons resistant to the action of fats, blood and deteratives. Considering the large volumes of water used in the different operations, it is necessary to wear PVC non-slip shoes, possibly with a steel point. Most of the processing cycle takes place inside a cold area; for this reason operators will frequently have to go, even though for short periods, from a room at normal temperature to one with temperatures on the order of 0 to 4°C. It is thus a good idea to include among personal protective equipment husky jackets, possibly sleeveless to allow greater freedom of movement in butchering operations. In the use of machinery, besides the gloves mentioned above, there must also be protective equipment to limit the effects of noise on the eardrums. Friction between the mechanical parts of machinery produces a series of disturbing noises that must be attenuated. Valid instruments in this case are earmuffs and earplugs for the protection of the ears.



Figure 2. Protective rubber and aluminium cloth aprons

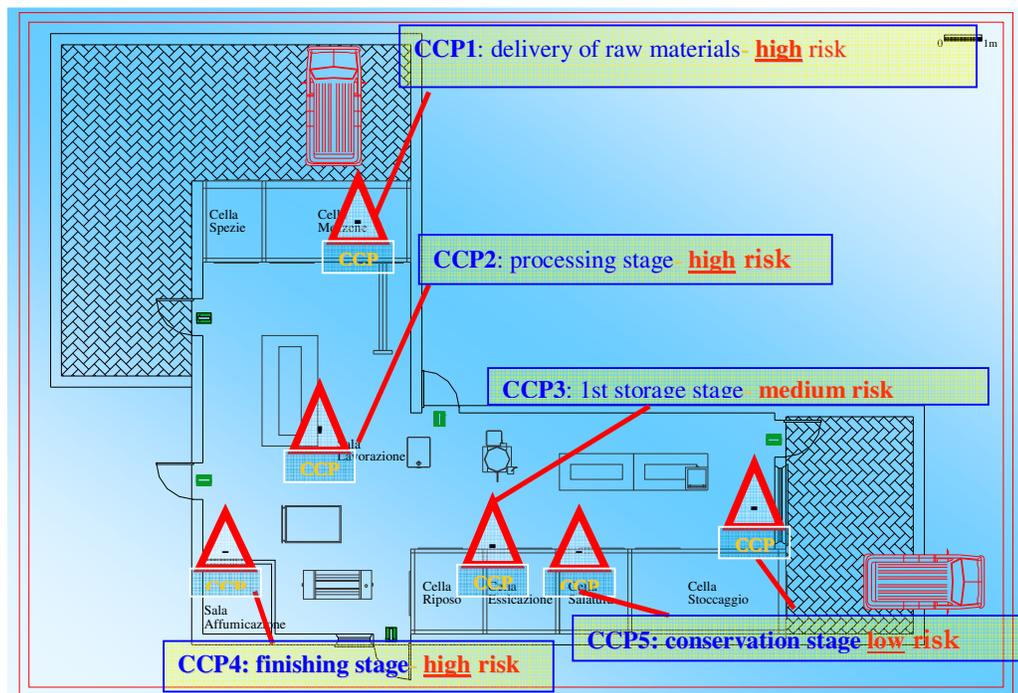


Figure 3. Critical points in the work cycle in a generic sausage factory

Conclusions

The proper application of the rules contained in legislative decrees 626/94 and 155/97 in the food industry in general, but more specifically in small sausage factories, imposes a new design approach, one that leads to the elimination, or maximum attenuation, of dangers and risks both to the product and to operators, without being detrimental to high efficiency and functionality. Buildings and equipment necessary for processing may, if not carefully chosen and arranged following good layouts (especially for the control of noise pollution), lead to the creation of serious dangers, not only those caused by improper use of tools and machinery, but also lead to traumas caused by carelessness in the design stage. The application of safety regulations improves the organization of the work cycle and makes it more efficient from the standpoint of the reaching of the highest quality and healthiness of the product.

References

ARSIA Toscana 1998. Linee guida per l'applicazione del D.Lgs. 155/97 nelle aziende agricole toscane. Settore viticolo – Florence, October 1998.

Pisanu M., Denti M. 2000. Influenza delle normative relative alla sicurezza e all'autocontrollo di qualità nella progettazione di edifici agroindustriali. Proceedings of the National Conference on "Le Costruzioni per la produzione agricola e il territorio rurale". Bologna, 19-20 October 2000.

Pisanu M., Denti M. 2000. La progettazione integrata: un metodo per garantire qualità e sicurezza negli edifici agroalimentari. Proceedings of the International Conference on "Produzioni alimentari e qualità della vita". Sassari 3-8 September 2000.

Pisanu M., Denti M. 2000. La progettazione degli impianti oleari secondo le norme HACCP e della sicurezza. Proceedings of the National Conference on "Le Costruzioni per la produzione agricola e il territorio rurale". Bologna, 19-20 October 2000.

Denti M. Pisanu M. Paschino F. 2002. Sicurezza e igiene negli stabilimenti enologici. Possibili interventi su macchine e strutture edilizie. Proceedings of the National AIIA Conference on "La sicurezza delle macchine agricole e degli impianti agro-industriali" pp. 411-418. Alghero, Sassari. 11 - 15 September 2002.

Trends in productivity over the day's work in Southern Italy forestry yard

D'Antonio P.¹, D'Antonio C.¹, Evangelista C.¹, Moretti N.²

¹ *Università degli Studi della Basilicata. Dipartimento Tecnico Economico per la Gestione del Territorio Agricolo e Forestale*

² *Università degli Studi della Basilicata. Dipartimento di Scienze dei Sistemi colturali, forestali e dell'ambiente*

Via dell'Ateneo – 85100 Potenza, ITALY. Tel 0039 0971205471, Fax 0039 0971205429, dantonio@unibas.it

Abstract

The purpose of this work was to analyse the changes in labour productivity performance in a forestry yard over the day taking into the account the specialisation of the workers, the organization of the yard and the respect or safety devices during the operation of filling and equipping wood.

The trials were done in a high forest oak. It has been created a circular fixed area plot, including the plants to fell, and were measured the diameter, the height and the volume of each tree of that area.

At the beginning of the working day have been collected information about workers.

The working time of the yard forestry were reported during the stages of felling, limbing and bucking-cut in three different moments of the day.

In terms of the organization of machineries and workers, in the yard there were not a tirfor, a wince and forest tractor.

The results showed an effective organization of the job thanks to a rational alternation of the workers which guaranteed a good level of labour productivity performance. Even if the break of few minutes at the end of each hour didn't decrease enough the level of fatigue connected to the use of a chain saws.

Concerning the trend in productivity of the yard during the work day it was clear that after the lunch the productivity decreased about of 15 %.

Moreover, during the trials we registered a poor use of any personal protective equipment (PPE).

Keywords: working day, accident, safety.

Introduction

The Italian forest is estimated at about 10 million hectares with an annual increase registered in the last decade, equal to 0.3%. Of this high surface more than half is covered by forests managed to coppice, stressing the spread of a species in light of the crisis that has affected the market for firewood during the second half of last century (Jordan, 1981).

In particular, these are the most coppice or coppice with standards and to be considered in crop abandonment in the time between one shift and the subsequent (Ciancio et al., 2004).

The lack of planning also due to the type of property (more than 50% of them are privately owned) and the extension lower average per hectare, leads to an irrational exploitation of the resource wood (Ciancio et al., 2004).

In addition, the operations of forest uses are usually performed only using the chain saws, slaughter processing equipment, and with agricultural machinery extraction equipment, where the morphology of the places allows. These traditional techniques in the past have registered low labour productivity (Febo et al., 1997; Pipitone at al., 2002; Pipitone at al.,

1992). Do not forget also that often working conditions, poor yields by orography land, are of high fatigue of operators with consequent reduction in productivity of the yard. This work was conducted, therefore, in order to analyse processing equipments in the productivity of a yard forest of southern Italy, during a single working day.

Materials and methods

The tests were conducted at a forest ruled a oak coppice privately owned site in Basilicata Short Wood System, as type of foret utilization, which consists of:

- Felling;
- Processing equipment, namely delimiting and cutting on the bed of fall up to 3 cm in diameter, drums landed length of approximately 1 m, typical of firewood;
- Yarding in separate piles, wood and brushwood;
- Extraction equipment the set loader crawler.

Before starting the trials, was conducted a test, whose plants have been subjected to dendrometric measures fundamental to obtain a comprehensive characterization of population under investigation. The following table shows the measurements made and the instruments used.

Table 1. Measurements and instruments used

MEASUREMENTS	MEASURING INSTRUMENTS	CHARACTERISTICS
Delimitation area wise	Measuring roller, Plastic tape	Radius of 20 m
Measure of diameter	Dendrometric caliper	
Measure of the eights	Hypsometer of Blume Leiss	
Relief periods of work	Stopwatch	

For each test field were made the following points:

- ✓ Equipment used;
- ✓ The number and level of specialization of operators in different stages of work;
- ✓ Organization of the yard;
- ✓ Time-working site;
- ✓ Amount of processed wood.

Specifically were found time for use in:

- Felling;
- Limbing;
- Bucking cut.

The methodology of the major periods of work was proposed by Berti et al. (1989) for forestry work, by adopting the method of observation of the various phases of work at regular intervals of two hours in three different time slots corresponding at 9 and 11 in the morning and at 14 in the afternoon. Through this approach, in fact, you can record the stages of work and have an overall percentage of knowing the same period of observation.

Regarding the made of processed wood, were made some measurements on full load.

Finally, during tests, has also registered the degree of use of devices Protective Equipment by operators.

Results

Characterization of forest site

The forest was located in Basilicata. That was a oak coppice with a prevalence of *Quercus cerris* and *Quercus pubescens* and, as the secondary species, *Carpinus betulus* with very dense undergrowth, consisting of hawthorn, ivy, broom and asparagus and that hinders and makes sporadic renovations.

The density of the wood is high with average distance between plants amounted to 2.5 meter and 1600 plants per hectare.

The soil has a discrete inherent fertility but the percentage of skeleton is low. And nature of clay mixed with a discreet presence of silt.

The slope within the forest is not uniform but oscillates between the second and third class.

The internal road network is good and is characterized by the presence of many paths that facilitate the achievement of the forest by the machines.

Equipment used

In the yard forest in question were used the following equipment:

- a) 2 chain saws;
- b) 1 loader crawler;
- c) 1 tractor;
- d) 1 accepts;
- s) 1 billhook.

Here are the technical characteristics of chain saws.

Table 2. Technical characteristics of chainsaw.

Weight without rod	6,5 kg	
Power	4,4/6,0 kW/HP	
Ratio Weight/Power	1,5 kg/kW	
Chain	Oilomatic Rapid Super	
Cut length	40, 45, 50 cm	
Capacity	76,5 cm ³	

Number and specialization of operators

In the yard in question there were 4 operators who were assigned to different tasks and whose degree of specialization is shown in Table 5:

- 1 specialized worker employed by felling;
- 1 worker generic train bucking cut and limbing with chain saws;
- 1 worker generic crew limbing improved by cutting waste stumps with a billhook and burning of brushwood overnight on the spot;
- 1 tractor driver for transporting timber from the bed of a fall to the place of loading trailers.

The culling operations and processing equipment were carried out by a team consisting of three workers: one chain saw operator, one helper and a one general worker. The assistant, during the preparation for the cut, had the task of making free the working area to enable the chain saw operator to make it easier cutting, and thereafter provided to remove from the work

that hindered the brushwood cutting operations, then indicated to chainsaw operator the area of the trunk on which make the cut for wood the same length. The utility man improved the limbing and proceeded to end the working day to burning of slash.

In this work, we have not given the manner and timing of extraction equipment as they were carried out in subsequent days and we concentrated on transactions involving felling and processing equipment of timber.

Table 4. Characterization of the team

Operator	Specialization	Age	Years of experience	Annual period of work (days)
1	Chainsaw operator	47	15	150
2	Utility man	25	5	120
3	Utility man	22	5	120
4	Tractor driver	60	40	150

Organization of the yard

The shipyard provided for the conduct of the following phases:

- 1) felling: including cleaning the area around the tree to be removed through the use of chain saws;
- 2) limbing and bucking cut. This was no separate operations in a net. The first was the disappearance of branches, the second in the trunk cut into pieces measuring default of about 1 meter through the use of chain saws;
- 3) arrangement of material cut in several piles on the bed of fall;
- 4) transfer of timber through a loader crawler or a tractor in an area not far;
- 5) load on the truck trailer;
- 6) further transport by truck.

Time Work

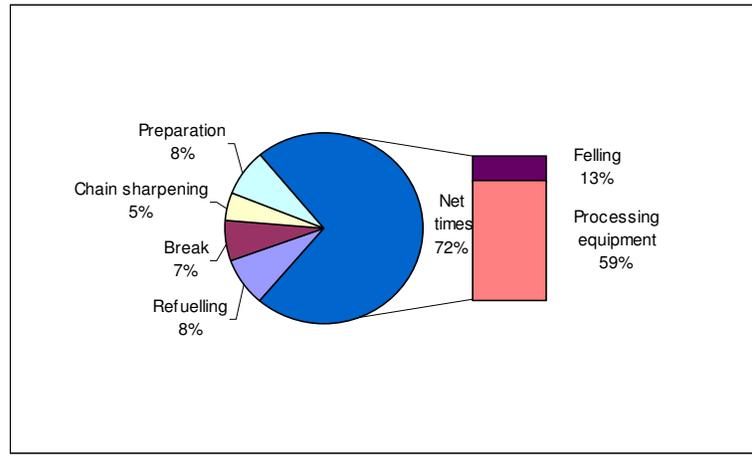
Regarding the timing of work, the yard forestry began his working day at 7:00 to end at 16:00 with a break for lunch from 12:00 to 13:00.

The surveys conducted are served to obtain the following parameters:

- Total time (TT) available for work, calculated by adding the times net (TN) and idle time (TM) transfer and preparation of all work;
- When net work (TN) during which men and means are actively committed to play the different production phases of work;
- Idle time work (TM) during which men and means are present at work but are engaged in preparatory stages of work, the transfer of equipment, maintenance of the same or, in case of accidental breakage of any component, repair and / or replacement of the latter, and not engaged in production phases.

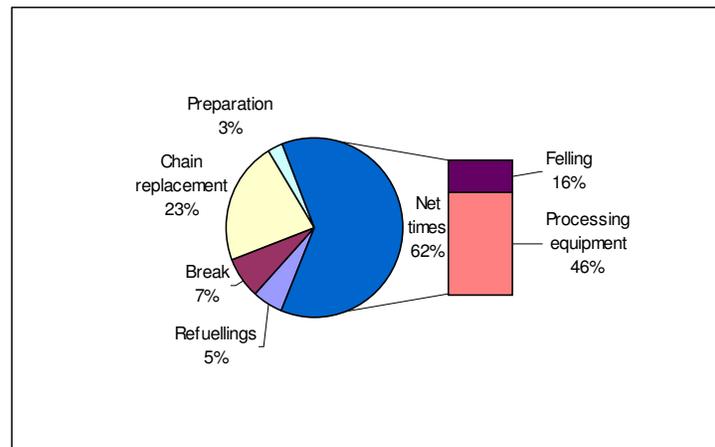
For the purposes of this research were recorded times on the use of plants with a diameter of between 12 and 52 cm.

In the first daypart time net used for the felling and processing equipment had an incidence rate, respectively 23% and 49% of the total. Graph 1, which contains specific times to the felling and their exhibition, shows that the time for the rest accounted for 14% on the total time, sharpening the chain of chain saws for 6% and supply of chain saws for 8%.



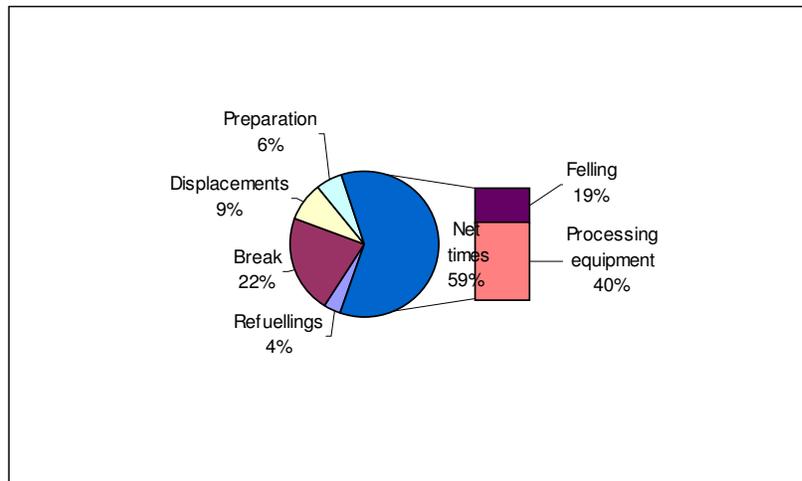
Graph 1. Trend in productivity during the first time band

In the second time band time net used for the felling and processing equipment had an incidence rate, respectively 13% and 59% of the total. Graph 2, which contains specific times to the felling and processing equipment, shows that the time for the rest accounted for 7%, and then to a lesser extent than the first time since the team was able to benefit the stop is necessary for replacing the chain of chain saws, as a result of accidental breakage.

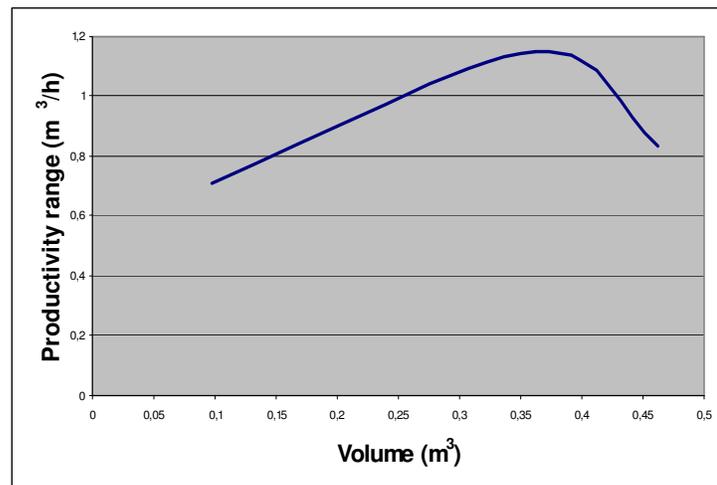


Graph 2. Trend in productivity during the second time band

In its third time band time net used for the felling and processing equipment had an incidence rate, respectively 16% and 46% of the total.



Graph 3. Trend in productivity during the third time band



Graph 4. Trend in productivity during the working day

In the graph 4 we illustrated the trend of productivity range related to the volume of wood felled during the working day.

Conclusions

From the data collected from field trials can draw the following conclusions:

- The characterization of forest site shows that the dense undergrowth and the slope make working conditions inconvenient and cause further fatigue for operators;
- Considering the equipment used, it was clear a no so accurate routine maintenance;
- Concerning the team, this was composed of a sufficient number of workers but with an insufficient degree of specialisation. In this regard, it would be appropriate that the second worker, employee use of chain saws, were specialized to optimize the yard work and to ensure the safe use of this equipment;

- Analysing the time work has shown a substantial increase in rest periods from first to third time band with a consequent reduction in the operational capacity of the yard;
 - Assessment of the yard in terms of machines and men showed the complete lack of tools to help main engine for felling (tirfor, winches and tractors forestry);
 - The average volume shot down over the three slots was equal to 0,307 m³ and productivity average of 0,898 m³/h man with a pek value of 1,15 m³/h per man registered at 11 in the morning. A clear fall in productivity of the yard was recorded during the afternoon time slot closely related to the sense of fatigue by the worker.
- Finally, during the field trials there was a reduced use of personal protective individual and a lack of information on security risks they run operators.

References

Berti S., Piegai F., Verani S. 1989. Manuale d'istruzione per il rilievo dei tempi di lavoro e delle produttività nei lavori forestali. Quaderni dell'Istituto di Assestamento e Tecnologia Forestale, Università di Firenze, Fascicolo IV. TIPOGRAFIA NOVA, Lastra a Signa (FI).

Ciancio O., Nocentini S. 2004 – Il bosco ceduo. Selvicoltura Assestamento Gestione. Accademia Italiana di Scienze Forestali, Firenze, 721 p;

Febo P., Pipitone F., Peri G. 1997. The preservation of sicilian forests with poorly mechanized logging processes. Journal of Agricultural Engineering Research, 67, 229-233;

Giordano G. 1981. Tecnologia del Legno. Vol. 1, pp. 1165-1175. Ed. UTET, Torino;

Pipitone F., Calafatello A.R., Catania P., Vallone M. 2002. Selvicoltura siciliana e attuali limiti di meccanizzazione. Atti del Convegno Il ruolo della meccanizzazione per il rilancio della selvicoltura in Calabria, 67-78;

Each author contributed to that paper in the same measure

The incidence of injuries in forestry

Colangelo M., D'Antonio P., D'Antonio C. , Evangelista C.
*Dipartimento Tecnico Economico per la Gestione del Territorio Agricolo e Forestale.
Università degli Studi della Basilicata.
e-mail address: dantonio@unibas.it*

Abstract

The aim of this work was to investigate about the causes of accidents in the forestry yard studying the international, national and regional literature available. The forestry worker represents a high-risk category because needs a high level of attention and of physical strength during his performance, in order to eliminate or reduce the risk or extent of the potential harm. The data analysis, from a Central statistics institute, was be useful to evaluate the respect of the safety devices and the problems due to the hard shift and over time work.

The results of this study clearly showed that the few numbers of injures registered was to explained with the presence of concealed workers. The risk of the accident increase, in particular, for the older workers (age between 40 and 65 years) as such as the 70% of them have been interested by an accident in workplace because of by-passing a safety devices during the use of the machineries, of a difficult job conditions and of the cumulative fatigue which increases the risk of damage and downfall.

Infact, the most important causes of injuries are the harms from work tools (13,3 %), followed by harms from vegetation (9,08 %) and dawnfalls in the workplace (6,72%).

In the future it's recommended following a guideline provides guidance to officers in the forest industry regarding accountability and responsibility for aspects of health and safety compliance in forestry operations.

Keywords: accident, safety, harm.

Introduction

This research includes an investigation and an analysis of accident incidence in the forest sector, so as characterize them as in a highest risk sector, due to accidents and occupational diseases. We described the European, Italian and Basilicata situation, so as to identify the system critical points, cause of existing situation, providing management solutions in order to handle the problem by available means, foresee the situation improvement. To this day the woodman is a key figure in the forest utilization and handling operations process; for this reason he has an abundant fund of knowledges and experiences, able to work cleverly and safely, avoiding that the wood, apparently a place innocuous and balanced, turn into a place of accident and death. Of course that is not suffice, it is necessary whether the correct application of work techniques or the use of appropriate tools to preserving workers and anyone, trying to preserve the ground and the wood from harms.

Materials and methods

Firstly we studied the statistic data about the forest accidents, starting point for the graphical representation of the present situation. The investigation was based on the analysis of accident statistics, whose sources were the most important statistic institutes us INAIL, ISTAT, ISPESL, of observation on European, National and Regional scale.

They were essential for the study of accident phenomenon development and to test out adequacy of preventive and insurance systems, to study and propose/suggest normative and technical solutions necessary to reduce the accident and occupational disease phenomenon.

We provided the exact definition of work accident, in accordance with law on insurance compulsory tutelage managed from INAIL, including: *"all accident events owing to violent cause during the work, from which rise the death or a permanent disability, absolute or partial, in other words an absolute and a temporary disability, causing the work abstention for more three days"*. (From the Dictionary of union and work terms - Edit Coop 2002).

This definition includes also other terms that need further clarification. Firstly the wording "violent cause" refer to external, unexpected and unforeseen factor, that quickly and intensely causes a damaging effect, including whether the aggression that damage psychophysical integrity of the worker or an action due to microorganism or to a physical strain causing torn muscle etcetera. The wording "work occasion" indicate that there is a cause and effect relationship among the working activity of the injured and the accident, although indirect. "Industrial injury" includes all events that cause material and person damages.

The forest worker operates in a place, the wood, where he is exposed to many risks, summarized in the table 1, which reports also the resulting damage and necessary interventions to prevent them. Further there are the risks due to wrong use of machineries and equipments.

Table 1. Generic risk and preventive actions for those who work in a wood (Reference: Hippoliti e Piegai, 2000)

	DANGER PRODUCED BY...	RISK CAUSED BY....	POSSIBLE HARM	PREVENTION'S INTERVENTION
RISK CAUSED BY ANIMALS	Small mammals, poisonous snakes, ticks, insects	Bite, sting, infection	Tetanus, rabies, trasmission of diseases, anaphylactic shock	Vaccination, informations about possible pathology on the regions at sea and about emergency provision
RISK CAUSED BY VEGETATION	Trees, shrubs, blackberry bush	Branches fall, lashes and blows against branches and spines	Hurts, crushings, lesions (eyes), borings	Use of PPE, informations about plain dealing
RISK CAUSED BY GROUND OROGRAPHY	Slope and casualness of the ground, presence of snow, ice, rain	Downfall, slip	Sprains, fractures, lesions	Use of PPE (soles high adherence)
RISK CAUSED BY ATMOSPHERIC CONDITIONS	Temperature, sun, meteoric agentes, thunderbolts	Exposure to high and low temperatures, to snows or rain, humidity, exposure to sunbeams, electrocution	Frost-bite, dehydration, stress, sunstroke, burn, hurts, lesions (death)	Work sossension, appropriate clothing, temporary shelters, use PPE

At the present time the available means to the forest worker to face up various risk situations, which he is exposed every day on the work place, classifying in *legislative* and *practical*. Both are connected to Legislative Decree 626/94 and in the first case we refer to obligations deriving for the employer who must supervise under provisions of the law and, on the strength of the risk evaluation, to take preventive measures most proper to the case. The practical means, better-known as Personal Protective Equipment (PPE) for operator, include all precautions that the worker must to wear in order to avoid and reduce the damages due to use of equipments, to the impact of various materials or to downfall, as illustrated in the figure 1.

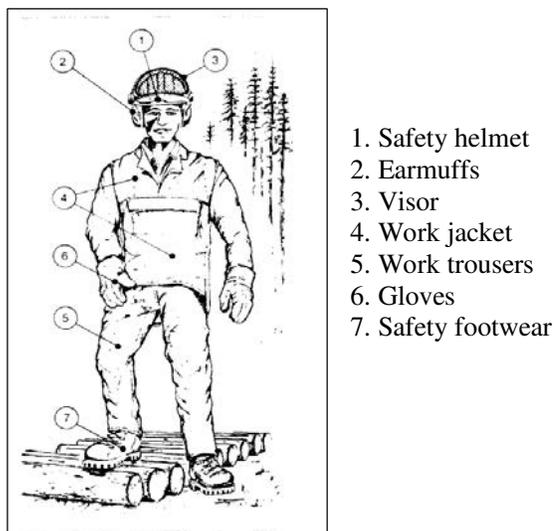


Figure 1. Forestry worker wearing Personal Protective Equipments (PPE)

Results

The analysis of the data pointed out a worrying picture of the situation; in the agricultural field which includes also the forest sector, the accident risk is high and concerns especially the operators aged between 40 and 65, for the 70%. These accidents are connected to use of machineries and equipments which cause downfall, hurt and limbs contusions. Until May 2008, due date of Legislative Decree 626/94 and become effective of D. Lgs. 81/2008, the application of guardianship law for workers had many difficulties. In fact the enterprises submitted to this decree are 350.000, because are excluded the family concerns and those outsourcing; unfortunately in these excluded firms happened the 70% of injuries. Starting from this datum and by a simple calculation emerged that about 80% of operators in this field was devoid of every safeguard. The data processing pointed out many curious and unexpected aspects.

The first data analysed were those relevant to the body regions most involved by lesions. The graph 1 reports the accident frequency in every body region.

The regions most affected were the upper limbs (42%), then the lower limbs (38%); it is curious their correspondence to personal protective equipment location.

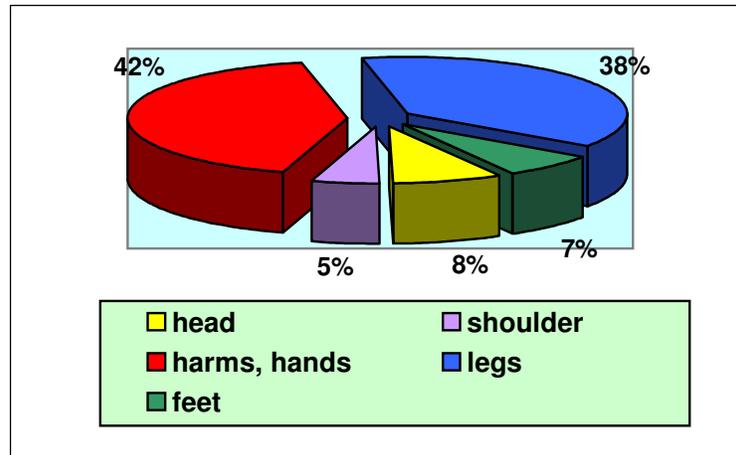
In the graph 2 it is possible to analyse the incidence of injuries in the European Union, registered in the period 2000-2004.

The nations with greater number of injuries are also those that present a most high silvicultural vocation; we refer to nation as Germany, Spain, Italy and France.

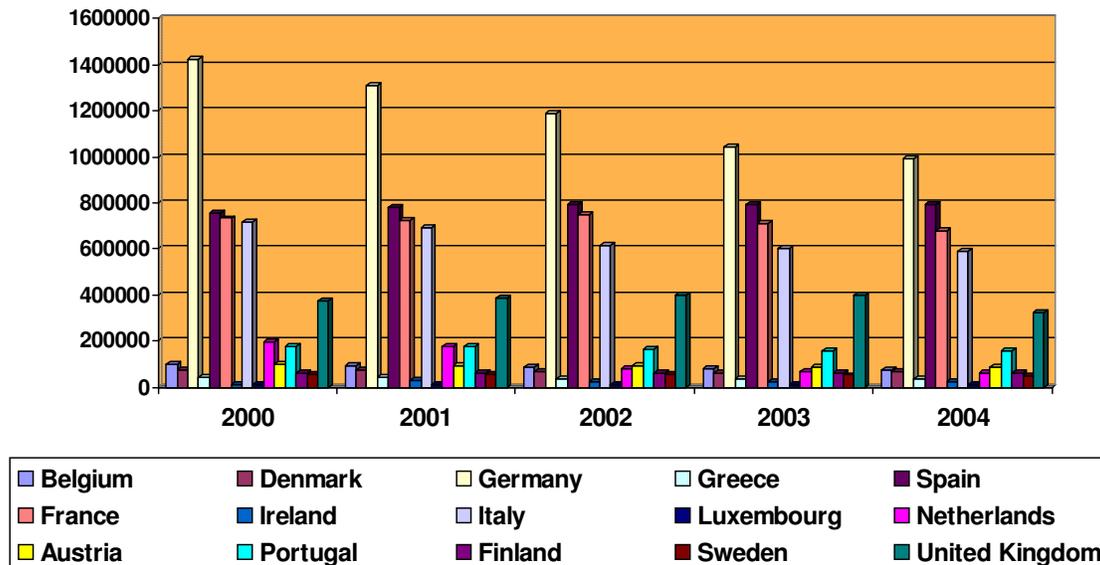
These countries have in common some aspects:

- high percentage of territory occupied by woods;
- growing volume of wood market in the country economy;
- reduced vigilance and control activity for observance of the safety regulations.

In this period there were a gradual reduction of the events, that have peaked in the 2000 in Germany, from 1.424.660 injuries until 990.193 in the 2004, datum related to the same country; very probably thanks to greater energies employed in the improvement of management and prevention activities.



Graph 1. Accident frequency for body's region

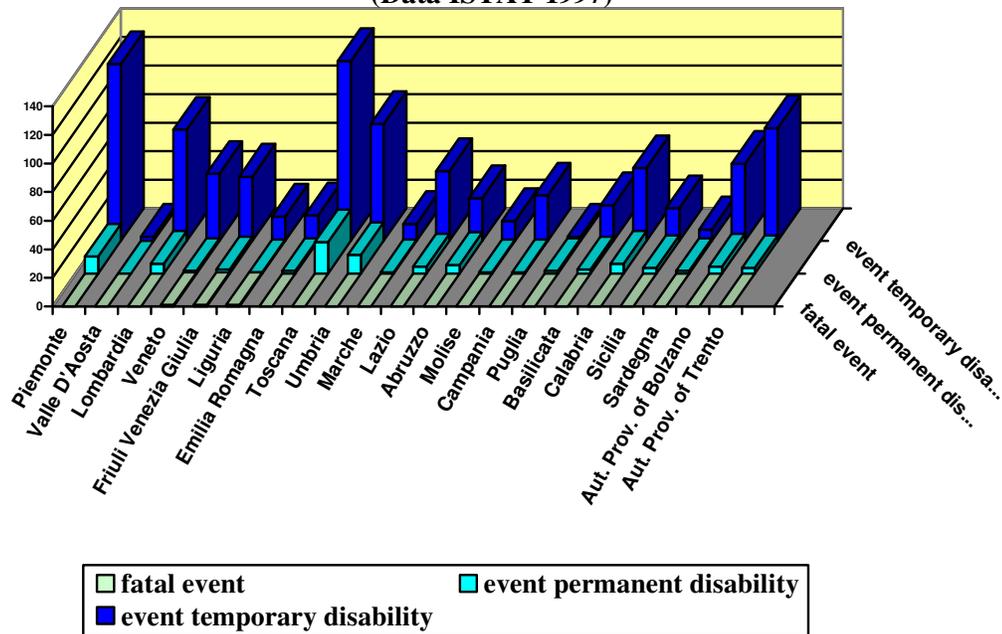


Graph 2. Accident at work in the European Union, 2000-2004 (Reference: INAIL)

The northern countries as Sweden, Denmark and Finland show a high respect of safety regulations but also a low density of population, reducing significantly the injuries risk. Analysing the national situation we can deduce that there was a considerable reduction of injuries equal to 18%, even if in this period the incidence of injuries was high compared with other European countries.

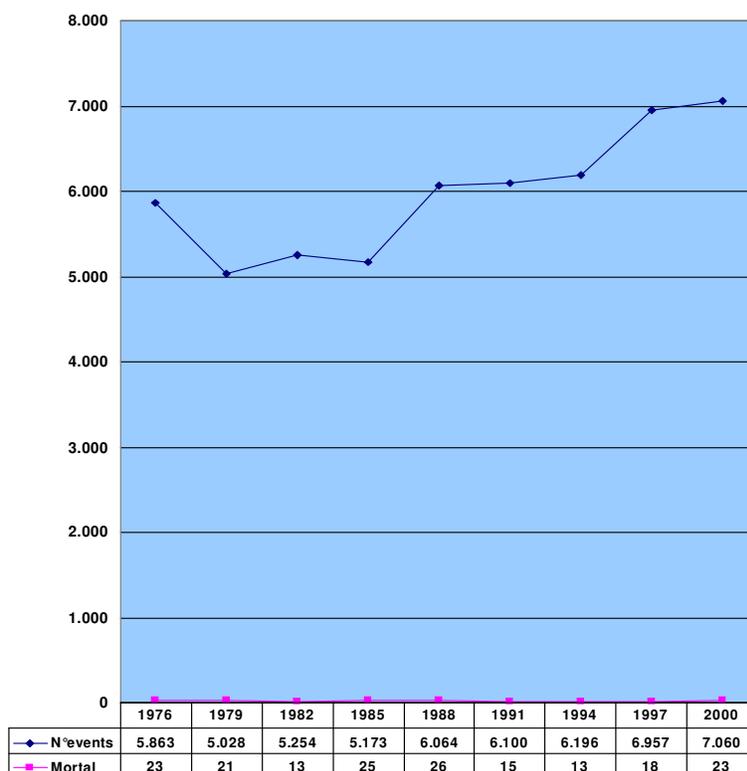
The events was characterised on the strength of the inability, if temporary or permanent or causing the operator death. The results are in the graph 3 and unlike to other graphs the data refer only forest utilization sector and to every Italian region, in the 1997.

Graphic 3. Event distribution for region of Italy and gravity of inability
 (Data ISTAT 1997)



Piemonte, Lombardia, Toscana, Umbria and Trentino Alto Adige present most high number of injuries causing inability. This datum is analogous to how much we observed in the graph 2; or rather, like so in Europe, the Italian regions with the greater number of injuries are those most rich in productive woods, with an intense utilization activity and a profitable wood market.

Particularly in the matter of the injuries happened in Basilicata (graph 4), we can make these observations. In the eighties was a growing rise of injuries, from 5028 in the 1976 to 7000 in the 2000; the injuries survey increased since 1988 while the mortal events decreased since 1994, year of Legislative Decree 626/94 passing. Unfortunately this datum doesn't indicate an injuries reduction in respect to past, but it is due to the obligatoriness of injuries registration, like so imposed by D. Lgs 626/94. Before 1994 the registration was compulsory only for those cases which needed sanitary cures at appropriate structure.



Graph 4. Agriculture: injuries in Basilicata (1976-2000)

Conclusions

In this research work we had various difficulties:

- the high level of underground job, scenario aggravated by several irregular immigrants and deficiency of controls from institutions, damaging the specialization of forestry workers and woodsmen, who were reached gradually thanks to care to guarantee a greater professionalism;

- imprecision and incompleteness of the data, due to inclusion of woody firms in the "Agriculture" sector, so in the forest statistics lack in a word that differentiates them. Further the agricultural enterprises often execute forest works too.

In the matter of injuries survey the firms submitted to D. Lgs. 626/94 are relatively few compared to totality, being excluded those family management and those outsourcing. Thereof we infer the gravity of current situation and that the most of operators is devoid of tutelage. The passage of the D. Lgs. 81/2008 on the 15th of May 2008 is a turning point in the prevention, in the fight against white deaths and in the underground job. In fact it contains the rules of the former Decree and other significant novelty concerning mortal accidents, underground job and sanctions.

Consequently for the future we are hoped for controls most strict and consciousness raising of those people that put profit logic before worker's safety, giving importance only when it runs out and it derives an injury or the death.

This study was unintentionally a background for those that attempt the application of the D. Lgs. 81/2008, providing numbers and figures useful for a comparison among them.

References

Decreto Legislativo n° 626 del 19 Settembre 1994 - Tutela della salute e sicurezza dei lavoratori-.

Decreto legislativo n°81 del 15 Maggio 2008 – Tutela della salute e sicurezza sul lavoro-.

Edit Coop, 2002 - Dizionario dei termini sindacali del lavoro-.

Hippoliti G. e Piegai F.,2000 - Rischi generici e specifici delle operazioni in bosco-.

INAIL (Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro) - Banca dati infortuni e malattie professionali denunciati all'INAIL-; www.inail.it.

ISTAT (Istituto Nazionale di Statistica) - 5° Censimento generale dell'Agricoltura- Banca dati Basilicata -classificazione delle attività economiche Ateco 2002-; www.istat.it.

ISPESL (Istituto Superiore Prevenzione e Sicurezza sul Lavoro) -Banca dati infortuni sul lavoro-; www.ispesl.it.

OLAB (Osservatorio sul Lavoro in Bosco) opuscoli, manuali e articoli sulla “prevenzione e caratteristica usurante delle attività in bosco”.

Each author contributed in that paper in same measure

Human health benefits and energy saving in olive oil mills

Cini E., Recchia L., Daou M., Boncinelli P.

Department of Agricultural and Forestry Engineering - University of Florence

Piazzale delle Cascine, 15 - 50144 Florence

Italy

Tel 055 3288313 Fax 055 331794

enrico.cini@unifi.it, lucia.recchia@unifi.it, marco.daou@unifi.it, paolo.boncinelli@unifi.it

Abstract

Increasing greenhouse gas production are strictly related to high energy consumption in developed and developing country, causing indirectly human health damages. Besides every kind of industry, including agro-food industry, needs a remarkable amount of high quality energy (electrical energy). These two problems may be solved using renewable sources as biomass and agro-food chain residuals, but the effective convenience of this opportunity should be energetically and environmentally demonstrated for each case study.

In this paper energetic and environmental impacts of olive oil mill are evaluated, considering possible energetic utilization of by-product obtained during the oil extraction process. The solid content of pomace consists of crushed olive stones with a 18000 kJ/kg LHV, which may contribute to primary energy saving of the agro-food industry. This solution implies adequate requirements of thermal energy for the agro-food industry or the nearest users and implementation of suitable equipment to separate and burn this residual.

During an entire production campaign, the electric energy consumption and processed olive mass of a typical olive oil mill have been measured. The analysis has highlighted that the utilization of olive stones as solid biofuel improves some environmental indicators (greenhouse gases); nevertheless the energy balance of the extraction plant must be assessed, because the stone separation determines an high electricity requirement. The environmental impact of different scenarios of olive oil mill have been evaluated using LCA methodology in order to define possible energy process chains, to fix carefully the system boundary and to develop the allocation step.

Keywords: greenhouse gas reduction, olive oil environmental impact, olive oil by-products, olive oil mill energy saving.

Introduction

Increasing greenhouse gas production are strictly related to high energy consumption in developed and developing country, causing indirectly human health damages. On the other hand every kind of industry, including agro-food industry, needs a remarkable amount of high quality energy, i.e. electrical energy. These two opposite problems may be solved using renewable sources as biomass and agro-food chain residuals, but the effective convenience of this opportunity should be energetically and environmentally demonstrated for each case study.

In this paper energetic and environmental impacts of olive oil mill are evaluated, considering possible energetic utilization of by-product obtained during the oil extraction process. In fact, the solid content of pomace consists of crushed olive stones with a LHV of about 18000 kJ/kg, therefore this by-product may contribute to thermal energy requirements of the agro-food industry. This solution permits energy saving, but at the same time it implies adequate requirements of thermal energy for the agro- food industry or other users within a

distance of few kilometres and implementation of suitable equipment to separate and burn this residual.

During an entire production campaign, the electric energy consumption and processed olive mass of a typical olive oil mill have been measured; then the feasibility of the introduction of a stone separator has been evaluated.

The analysis has highlighted that the utilization of olive stones as solid biofuel can improve some environmental indicators (i.e. greenhouse gases); nevertheless the energy balance of the extraction plant must be assessed, because the stone separation determines an high electricity requirement.

The environmental impact of different scenarios of olive oil mill have been evaluated using LCA methodology in order to define possible energy process chains, to fix carefully the system boundary and to develop the allocation step. Inventory phase of the LCA has been developed using experimental data of different operative phases.

Materials and methods

The experimental olive oil mills are located in the Province of Florence (Italy) and they are representative for small and medium size farm plants (working capacity of about 500 kg/h of olives). The olive mills considered are characterised by similar working processes, layout plant, installed electric power, working capacity, quality level of the extracted olive oil.

The olive mill monitored for electric energy consumption measurements, process olives conferred within 24 hours since collection and its layout comprises the following steps: defoliation-washing, crushing, vertical kneading, two phases centrifugal extraction, filtration with cartons.

Working process parameters are shown in Table 1: the data are referred to the overall electric power employed in each process step, including submitted equipment (transfer pumps, cleaning pumps, fans, etc.), and to the single olive lot, whose average mass value is 298,77 kg.

Another similar olive mill, using a pomace stone separator after the oil centrifugal extraction phase, is considered to evaluate the impact of stone collection on oil mill energy balance (see Table 1). Considering an average solid content about 40% on olive mass, the efficiency of the stone extraction is about 15% on olive mass.

Considering three kinds of performed operation, energy consumption shares show (see Table 2) that

- about 40% of total mill energy consumption is used in olive conditioning operation, the can be assumed as the effective energy requirement of the olive oil mill,
- about 25% of total mill energy consumption is spent for mass transfer and more than 33% of this quantity is lost in mass temperature increase as shown in Figure 1.

These results don't consider environmental impact of pomace stone separator, related to increasing equipment (stone separator, boiler, piping system) need and commodity consumption related to pomace stone separator insertion in olive mill layout. Besides, recent extra-virgin olive oil production protocols target the minimum temperature increase of processed mass for nutritional content preservation, so it is necessary to use the available potential heat energy out of the olive mill, i.e. for energy need of other farm agro-food production chains or services.

Table 1. Working process energetic parameters

		Installed power	Time	% power exploitation	Energy consumption	Specific energy consumption
		[kW]	[s]		[kJ]	[kJ/kg]
defoliation-washing		1,77	1279,00	100,00%	2263,83	7,58
crushing	cutting	5,50	1279,00	51,40%	3615,733	12,10
	auxiliary equipment	1,86	1279,00	100,00%	2378,94	7,96
kneading		1,10	3600	100,00%	3960	13,25
extraction	centrifugation	15,00	1926	56,00%	16178,4	54,15
	auxiliary equipment	1,50	1926	100,00%	2889	9,67
filtration		0,75	242	100,00%	181,5	0,61
TOTAL		27,48	8326,00	66,26%	31467,4	105,32
stone separator		15,00	1926	66,26%	19141,2	64,07
TOTAL with stone separator		42,48	10252,00	66,26%	50608,60	169,39
Increasing due to stone separator insertion		15,00	1926,00	-	19141,20	64,07

Table 2. Analysis of energy utilization in the process

	Absolute value [kJ]	Specific value [kJ/kg]	%
Mass temperature increase energy consumption	10798,58	36,14	34,31%
Mass transfer energy consumption	7531,77	25,21	23,94%
Mass transformation energy consumption	13137,06	43,97	41,75%
Total energy consumption	31467,40	105,32	100,00%

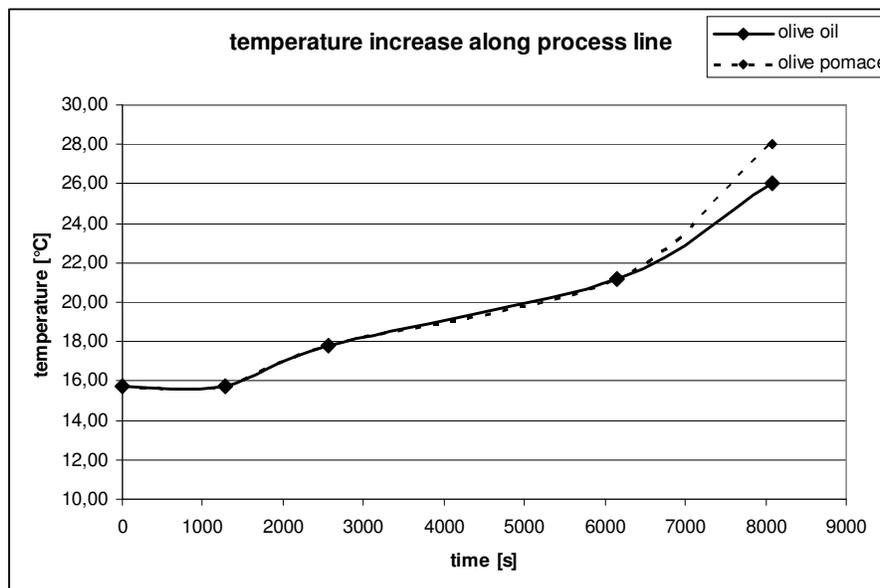


Figure 1. Temperature increase along the process line.

For environmental impact of pomace stone separator implementation in olive oil mills, an LCA analysis has been carried out. An olive oil production chain can consist of several processes: olive trees cultivation (soil preparation, fertilization, etc.), olives collection, olives transport from field to oil milling plant, olive oil extraction through mechanical plant. Along the whole agricultural chain, all emissions (GHG, air emissions and resources use) must be accounted.

In the energy-environmental analysis of production systems the following steps will be considered: system boundaries identification, reference energy system definition, all inputs and outputs (mass and energy) identification and quantification, energy embodied in facility infrastructure identification, distribution system analysis and by-product analysis.

In the present paper just considers the extraction process of olive oil, defining different case studies:

1. extraction process with oil production and pomace treated as waste (reference case);
2. extraction process with oil production and pomace used as fertiliser;
3. extraction process with oil and pomace stone productions;
4. extraction process with oil and pomace stone productions, using pomace residue as fertiliser.

The work has been developed in order to evaluate the environmental impact of olive oil production considering different possibilities for the by-product reuses (the reference case of the LCA hypothesise that the two phases pomace is treated as waste).

Concerning the milling plant, an operating time of 1200 hours for year has been considered hypothesizing that the plant will work continuously during about 2 months. The milling plant is able to treat 500 kg/h of olives using 792 kJ/kg of electricity supply without separation machine.

The work has supposed a fertiliser supplies of about 0,002750 kg of phosphorus, 0,006143 kg of calcium, 0,005143 kg of nitrogen, 0,009107 kg of potassium per each kg of pomace.

With the aim to evaluate correctly the possibility of energetic use of pomace stones the allocation of this co-product has been carried out using as replaced process the process of natural gas production (considering the Italian mix).

Results

As shown in Table 1, the insertion of stone separator in layout olive mill determines power, time and energy consumption increase. Considering olive mill energy efficiency related to stone separation insertion, crushed stone collection allows to make 44,82 kg of crushed stones available for each olive lot entering the process, using additional 64,07 kJ of electric energy (stone separator) for each kg of worked olives. It means that the consumption of about 19000 kJ of electric energy makes about 807000 kJ of potential heat energy available.

Analysing the LCA analysis results a significant benefit of the use of pomace as fertiliser (the spreading in field can reduce the amount of fertilisers) has been detected. Nevertheless the energy use of pomace stones has highlighted a consistent electricity consumption increase (more than 60%) due to separation equipment.

The LCA analysis main indicators for hypothesized scenarios are shown in Table 3.

Table 3. LCA results by GEMIS for 1000 kg of produced olive oil (CER = Cumulated Energy Requirement; CMR = Cumulated Material Requirement).

Emissions	CO ₂ equivalent [tons]	SO ₂ equivalent [kg]	NO _x [kg]	HCl [kg]	Particulates [kg]
oil mill 1	8,0	7,26	8,36	0,02	0,72
oil mill 2	2,1	3,68	5,82	0,00	0,33
oil mill 3	8,2	7,32	8,37	0,02	0,73
oil mill 4	2,6	3,73	5,82	0,00	0,34

CER	Sum [MWh]	Non renewable %	Renewable %
oil mill 1	3,39	99,2	0,8
oil mill 2	1,61	98,9	1,1
oil mill 3	3,02	98,6	1,4
oil mill 4	1,24	97,4	2,6

CMR	Sum [kg]	non renewable [kg]	renewable [kg]	other [kg]
oil mill 1	5,5 10 ³	5,7 10 ¹	5,4 10 ³	3,7
oil mill 2	1,4 10 ³	-6,7 10 ²	2,1 10 ³	3,2
oil mill 3	5,9 10 ³	5,8 10 ¹	5,9 10 ³	3,7
oil mill 4	1,8 10 ³	-6,7 10 ²	2,5 10 ³	3,1

Conclusions

This work has shown some interesting aspects of olive mill by-product utilization:

- pomace stone separation allows the olive mill to have a significant thermal power available with a minimum increase of electric energy consumption;

- field distribution (scenarios 2 and 4) determines strong reduction of emissions, especially GHG ones (about 75%), half energy (CER) and raw material (CMR) consumption;
- stone pomace recovery (scenario 4) determines additional energy savings, but causes increase of raw material consumption and mainly an increase of GHG emission with respect to the field distribution of the whole pomace mass (scenario 2).

As a conclusion, the availability of an additional thermal power from pomace stone energetic exploitation (scenario 4) for the single olive mill or farm allows a significant energy saving but as a draw back causes a GHG emission increase in olive oil production chain.

References

Barbari M., Cini E., Recchia L. 2005. La distillazione nel trattamento dei reflui da impianti zootecnici e dell'agroindustria. Proceedings of AIIA Congress, Catania, 27-30 June 2005.

Cini E., Recchia L. 2006. Filiere biomassa-energia in aziende agricole toscane: analisi territoriale, economica e ambientale. Proceedings of Congress “Esperienze italiane: risultati del progetto COFIN. Filiere Biomassa-Energia in Italia, politiche in atto”, Ancona, 21 December 2006.

Jungmeier G. 1999. LCA for comparison of greenhouse gas emissions of bioenergy and fossil energy systems. Proceedings of 7th LCA Case Studies Symposium SETAC-Europe, Brussels.

Recchia L., Cini E. 2005. Life cycle analysis for a comparison between energy from biomass and fossil for the requirement of a Chianti farm (Tuscany, Italy). Proceedings of 14th European Biomass Conference and Exhibition, Paris, 17-21 October 2005.

Recchia L., Vieri M., Cini E., Rimediotti M., Daou M. 2006. Nuova trincia raccogliitrice Nobili TRP-RT. M&MA, 2, 53-55.

Recchia L., Cini E., Corsi S. 2007. Life Cycle Analysis methodology applied to sunflower oil utilisation in Tuscany farms. Proceedings of 15th European Biomass Conference and Exhibition, Berlin, 7-11 May 2007.

Tenerelli P., Pantaleo A., Carone M.T., A. Pellerano, Recchia L. 2007. Spatial, environmental and economic modelling of energy crop routes: liquid vs solid biomass to electricity chains in Puglia Region. Proceedings of 15th European Biomass Conference and Exhibition, Berlin, 7-11 May 2007.