The heat stress for workers employed in a dairy farm

A. Marucci, D. Monarca, M. Cecchini, A. Colantoni, S. Di Giacinto, A. Cappuccini

Department of Agriculture, Forests, Nature and Energy (D.A.F.N.E.), Università degli Studi della Tuscia, Viterbo, Italy

Abstract

The italian dairy production is characterized by high heterogeneity. The typology quantitatively more important (80% of national production) is represented by cow's milk cheeses (Grana Padano cheese, string cheese, Parmesan cheese, etc.),while the cheese from buffalo's milk (especially string cheese such as mozzarella) and cheese from sheep and goats represents respectively 4% and 8% of the national dairy production, and are linked to specific regional contexts. Some phases of the cycle of milk processing occur at certain temperatures that not are comfortable for the operator also in relation to possible problems due to thermal shock. The aim of this study was to evaluate the risk of heat stress on workers operating in a dairy for processing of buffalo milk. The research was conducted at a dairy farm located in the province of Viterbo, Italy, during the spring-summer period. To carry out the research were detected major climatic parameters (air temperature, relative humidity, mean radiant temperature, air velocity) and the main parameters of the individual operators (thermal insulation provided by clothing and the energy expenditure required from the work done by employees in the work areas investigated). Subsequently were calculated main indices of heat stress assessment provided by the main technical standards. In particular have been calculated Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) in moderate environments, provided by the UNI EN ISO 7730 and the wet bulb globe temperature (WBGT) in severe hot environments required by UNI EN 27243. The results show some phases of risk from heat stress and possible solutions to improve the safety of the operators.

Introduction

Especially in Mediterranean areas the optimal temperatures are abundantly exceeded due to the high values of solar radiation, coming to 1000 W m^{-2}, and similarly for the high values of air temperature that during the summer can reach 40°C (Marucci *et al.*, *In Press*).

The issues related to the microclimate in the workplace are connected to the environmental factors that affect the thermal exchanges between man and the environment. In many agricultural and agro-industrial workplaces, the thermal comfort is difficult to achieve. In fact, the man is often found to operate outdoors or in the presence of animals, or in high temperature conditions (greenhouses) or very low (cold storage) or in situations where climatic parameters must be kept within specific microclimatic intervals, to ensure products conform to the standards of preparation, ripening and storage of products.

The main factors that influence these exchanges are: the weather conditions outside, the structural characteristics of the building, the characteristics of air conditioning (cold, hot), the number of occupants in environment to be examined and the type of activity.

Of particular importance is also, especially in the agro-food industries, the presence of thermal excursions such as to endanger the health of workers (Monarca *et al.*, 2012).

In dairy farms remain, even where the level of automation is high, numerous conditions of risk to workers' health (Di Giacinto *et al.*, 2012). Among these are included the sensation of thermal discomfort perceived by employees, caused to the microclimatic conditions (Marras *et al.*, 2005).

The milk processing within a dairy varies according to the type of product to be obtained with a consequent variation of the optimal microclimatic conditions which are often in contrast with those relating to the feeling of thermal comfort necessary for workers.

It is therefore necessary to analyze such working conditions, evaluate the impact on the worker's health and identify appropriate measures of technical, organizational and procedural be taken to improve the working conditions of staff (Marucci *et al.*, 2012).

The risk assessment of thermal stress is evaluated using microclimatic indices (Alfano *et al.*, 1998; Moran *et al.*, 2001; Pérez-Alonso *et al.*, 2011. Callejon-Ferre *et al.*, 2011) taken from the safety legislations that take into account climatic factors, the activities carried out by operators and clothing used (Budd, 2008).

The goal of this research is to assess the risk of heat stress for workers that operate within a dairy farm used as processing of buffalo's milk.

The research was conducted within a dairy farm located in a municipality of Alto Lazio, central Italy, during the spring-summer period and subsequent determination of the main indices of heat stress assessment provided by the main technical standards: UNI EN ISO 7730 for the determination of the Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) in moderate environments and UNI EN 27243 for the calculation of the wet bulb globe temperature (WBGT) in hot severe environments.

Materials and methods

The technical standards used for the risk assessment of thermal

Correspondence: A. Marucci, Department of Agriculture, Forests, Nature and Energy (D.A.F.N.E.), Università degli Studi della Tuscia, Viterbo, Italy.
Tel: +39(0)761.357365 - Fax: +39(0)761.357453.
E-mail: marucci@unitus.it

Key words: dairy farm, heat stress, microclimate.

Journal of Agricultural Engineering 2013; XLIV(s2):e144
doi:10.4081/jae.2013.s2.e144

stress are those represented by the ISO standard, implemented in Italy as UNI. In particular, the following standards were applied:

- EN ISO 7730: 2006 Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria;
- EN ISO 27243: 1996 Hot environments. Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature);
- EN ISO 8996: 2005 Ergonomics of the thermal environment. Determination of metabolic rate;
- EN ISO 9920: 2009 Ergonomics of the thermal environment. Estimation of thermal insulation and water vapour resistance of a clothing ensemble;
- EN ISO 7726: 2002 Ergonomics of the thermal environment. Instruments for measuring physical quantities.

In order to determine the indices proposed by the reference standards were detected microclimatic parameters (temperature and relative humidity inside and outside) of a dairy farm (Figure 1) located in a municipality of Alto Lazio (Altitude: 464 m; Latitude: 42°32'17'' N; Longitude: 12°03'19''E) during the spring-summer period. The measurements were performed during the time of the mozzarella working (3 p.m.- 4 p.m.).

The measurement system used is the following (Figure 2):

1. multi-acquiring LSI BABUC M instrument with 6 inputs;
2. probes for measuring micro-climatic parameters (thermometer, psychrometer, anemometer and globe thermometer);
3. prop for probes;
4. tripod.

The probes were put into position on a tripod at a height of 1.50 m from the ground.

When measured microclimatic parameters were determined PMV and PPD.

The PMV (Predicted Mean Vote) is the average rating from a large sample of people present in the same environment14 and is a mathematical function (1) that depends on several factors:

$$PMV = f\left(M, W, I_{cl}, f_{cl}, t_a, t_r, v_{ar}, p_a, h_c, t_{cl}\right) \quad (1)$$

where:

M is the metabolic rate (Wm^{-2});
W is the effective mechanical power (Wm^{-2});
I_{cl} is the clothing insulation (m^2 K W^{-1});
f_{cl} is the clothing surface area factor;
t_a is the air temperature (°C);
t_r is the mean radiant temperature (°C);
v_{ar} is the relative air velocity (m s^{-1});
p_a is the water vapour partial pressure (Pa);
h_c is the convective heat transfer coefficient (W m^{-2} K^{-1});
t_{cl} is the clothing surface temperature (°C).

To determine climatic parameters have been used climate data collected on the farm, while the metabolism rate (M) and clothing insulation (I_{cl}) of workers have been determined on the basis of existing legislation. It was taken on a metabolic rate (M) equal to 116 W m^{-2} (2,0 met) as reported in legislation that corresponds to an medium activity and standing. The clothing used by workers is underpants, boiler suit, socks, shoes that corresponds to an I_{cl} equal to 0,75 clo (0,11 m^2 K W^{-1}).

ISO 7730 defines the scale of values of the PMV in range +3 (very hot) to -3 (very cold). There are intermediate situations where the 0 corresponds to thermal neutrality, the range between -0.5 and +0.5 corresponds to the thermal comfort. When -2 <PMV <-0.5 and +0.5 <PMV <+2 the thermal environment is moderate while the PMV values less than -2 and greater than +2 the thermal environment is severe.

The same standard defines PPD as the percentage of thermally dissatisfied people14 and is calculated according to the following function (2):

$$PPD = 100 - 95 \cdot e^{-\left(0.03353 PMV^4 - 0.2179 PMV^2\right)} \quad (2)$$

The PPD is equal to 10% in the case where the PMV is within the range of thermal comfort (-0.5 <PMV<+0.5), while for severe environments the PPD assumes values higher than 80%.

PMV has allowed us to classify the thermal environment into consideration as hot.

Consequently, it was necessary to calculate another index proposed

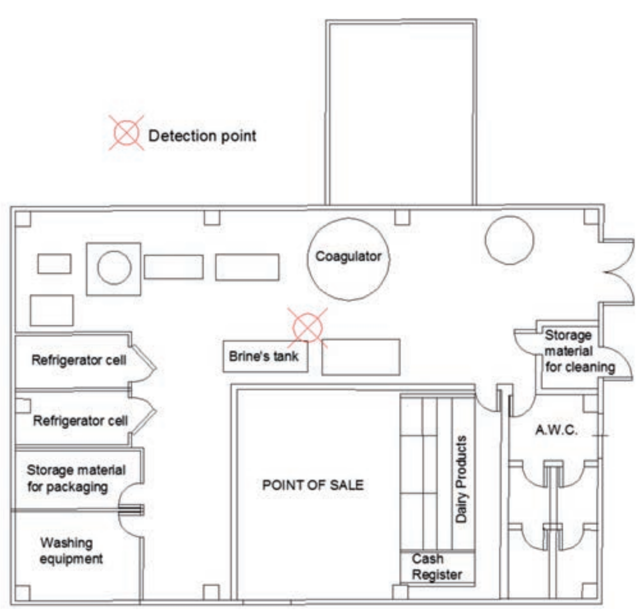

Figure 1. Plan of dairy farm object of study.

Figure 2. Measurement system used for the research.

legislation for harsh hot thermal environments: WBGT (Wet Bulbe Globe Temperature).

WBGT is used to determine the thermal stress for individuals acclimated. The current legislation proposes two equations for calculating the WBGT as a function of the presence or absence of sunshine. In this farm, the interior lighting is completely artificial and therefore without the entry of sunlight. Therefore, the equation that has been applied is that relating to environments not sunny (3):

$$WBGT = 0.7t_{nw} + 0.3t_g$$

for internal and external exposition without exposure to sun (3)
where:
t_{nw} is Natural wet-bulb temperature (°C);
t_g is globe thermometer temperature (°C).

The days when the measurements were performed are:
- April 10th, 2013;
- May 3rd, 2013;
- May 30th, 2013;
- June 11th, 2013;
- June 17th, 2013.

Results and discussion

The measured values of temperature and relative humidity of the air and the calculated values of PMV and PPD during the processing of milk in the test period have given the mean values reported in Table 1:

From the measurements performed in this period, the indoor air temperature is always higher than 20°C. In the last two measurement periods, which fall in June, the indoor air temperature was higher than 25°C.

The high values of the indoor air temperature in the dairy farm are due to the processing of milk and are positive for the production of mozzarella but they can cause serious health problems of the operators especially in the event of prolonged exposure.

The relative humidity measured inside the dairy farm is between 50% and 80%, has not been reached the saturation of the air and this has allowed to reduce the risks associated with the high air temperature.

Figure 3 shows the mean values of the PMV and PPD calculated with the measured values from 3 p.m. to 4 p.m. for each day of measurement inside the dairy and the limit (+2) beyond which the environment changes from moderate to severe hot.

On the first day of the experimental period (April 10), taking into account the thermal energy produced during metabolic activity by operators and thermal insulation of the clothing, the PMV is equal to +1.32 placing itself in the middle between "slightly warm "and" warm "in the seven-point thermal sensation scale reported by the legislation. The predicted percentage dissatisfied (PPD) associated with this PMV value was equal to 41.2%.

In the other days of measurements instead PMV index always exceeds the limit of +2 due to the high indoor values of air temperature and relative humidity measured, and other conditions being equal. Exceeding this limit allows to classify the processing environment as severe hot.

The day 17 June, the PMV was not calculated because the air temperature has exceeded the value of 30°C.

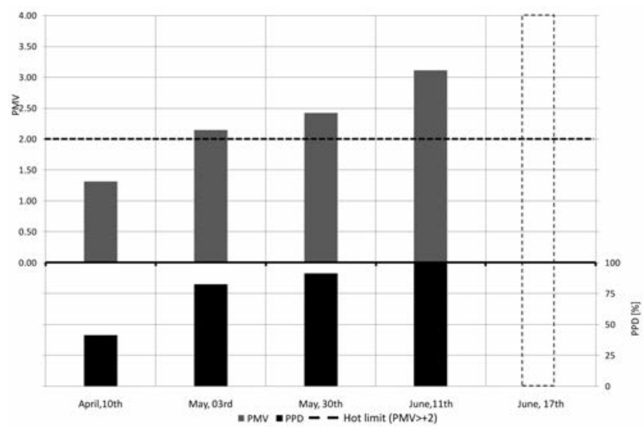

Figure 3. PMV, PPD and PMV limit established by the respective reference standards.

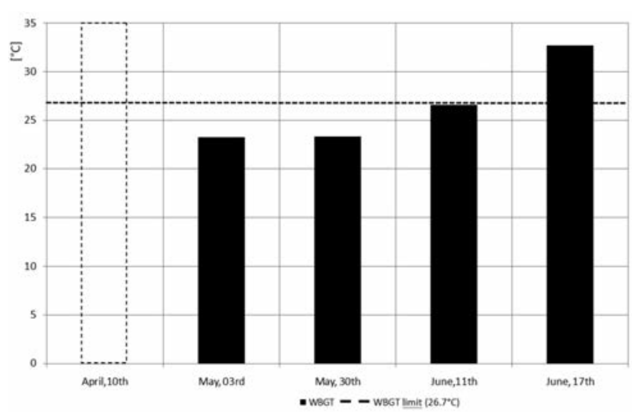

Figure 4. Mean values of WBGT index for the periods of experimentation.

Table 1. Mean values of indoor and outdoor air temperature and relative humidity, clothing insulation and metabolic rate.

	Indoor air temperature	Indoor relative humidity	Outdoor air temperature	Outdoor relative humidity	I_{cl}	M
	[°C]	[%]	[°C]	[%]	[clo]	[W m^{-2}]
April,10th	20.87	65.3	16.6	51.4	0.70	116
May, 03rd	22.90	64.8	21.1	59.2	0.70	116
May, 30th	22.75	78.4	17.1	56.6	0.70	116
June,11th	26.26	61.5	23.1	54.3	0.70	116
June, 17th	32.73	53.5	31.4	29.7	-	-

Where the PMV index exceeds the threshold of +2, and thus the work environment becomes “severe hot”, and the indoor air temperature exceeds 30°C is necessary to calculate another index proposed by microclimate safety regulations: the WBGT, through which it is possible to verify if operators are subjected to heat stress.

Figure 4 shows the mean values of WBGT index for the periods of experimentation and the limit for acclimated subjects (26.7°C).

For the first day of observation (April, 10th) has not been calculated the WBGT index because the working environment was found to be moderate (+0.5<PMV<+2).

The WBGT values calculated for the later days of relief are higher than the limit established by law for acclimated subjects (26.7°C) only in the last day of the measurements. During these reliefs the WBGT was found to be equal to 32.7°C showing how the workers were subjected to a real thermal stress.

In general, the search results allow to affirm that, under the climatic conditions in which it is located the dairy farm , during the second part of the spring season (late April-mid June) the operators are in the presence of a situation of thermal discomfort but they are not subjected to thermal stress since the WBGT was found to be always lower than the limit established by law.

To reduce the thermal discomfort you might act on operator’s clothing in order to reduce the I_{cl} index, a significant improvement of the conditions would be obtained to passing a clothing with I_{cl}=0.70 clo to another with I_{cl}=0.50 clo.

From mid June and for the entire duration of the hot season, the WBGT exceeds the limit set for acclimated workers and the employees find themselves operating under thermal stress conditions.

Since the WBGT index, unlike the PMV, is closely related to the air temperature you could intervene further reducing the value, whose control is generally entrusted only to the forced ventilation through fume hood.

Additional actions may be even the clothing of the operators described above and the programming of one or more breaks during the working shift to spend in areas of acclimatization.

Conclusions

The calculation of the indices, brought in accordance with the safety standards, has allowed us to assess the degree of risk of heat stress they are subjected to the operators involved in the preparation of buffalo’s mozzarella in a dairy farm.

The survey data showed the presence of different situations of heat stress risk.

During the second part of the spring season (late April-mid June) the workers of buffalo’s mozzarella, under the climatic conditions in which it is located the dairy farm, are in the presence of a situation of thermal discomfort because the calculated WBGT Index not exceeds the threshold established by the legislation.

In the last study period (mid-June) in the vicinity of the summer and in presence of significantly higher air temperatures, it is possible to affirm that operators are in presence of heat stress conditions.

In order to reduce this risk, the employer is required to:

- Provide appropriate clothing in order to reduce the I_{cl} index;
- Check the exposure times with programming breaks to spend in areas of acclimatization;
- Reduce the indoor air temperature of the workplace through an appropriate air conditioning system.

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