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Thermographic Images to Measure Health Risks of Workers Exposed to Artificially Refrigerated Environments

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ABSTRACT

Thermography generates high-resolution imagery in real time and is a non-invasive and painless technique devoid of physical contact or exposure to any type of radiation. This technique has been successfully applied to different areas, such as health- and safety-related applications, to control cold risk in workers exposed to low-temperature environments. Thus, this study aims to analyze skin temperature variations in three body parts of the upper limbs (fingers, the center of the hands and wrists on both the left and right sides of the body) caused by exposure to low temperatures in air-conditioned and artificially controlled work environments.

The objective is to assess thermography's adequacy in controlling workers' health risks. This study used environmental monitoring equipment and infrared radiation detection cameras to capture images of the body parts that were evaluated. The research was conducted on 20 workers from two sectors of a poultry slaughterhouse. Among the three body parts evaluated, the lowest temperatures occurred in the workers' fingertips, which averaged 16.86ºC. This fact may relate to discomfort, pain, decreased performance, functional imbalance and cold-related diseases caused by faulty conditions and/or the equipment used to ensure the workers' thermal comfort. It was concluded that the thermographic evaluation of activities that involve exposure to the cold is efficient, as well as feasible, when quantifying the potential threats of environmental cold to workers' health.

INTRODUCTION

Occupational diseases in workers exposed to artificially air-conditioned environments pose a serious health threat. Several diseases cited in medical literature can be linked to workers being thermally exposed to cold. Various industries, such as refrigeration, food processing, and ports, use refrigeration processes to ensure product quality and integrity, thus meeting the hygienic and sanitary standards applicable to perishable food production. Specific sectors, such as slaughterhouses and refrigerators, expose workers to environments with temperatures as low as -40°C, which results in a significant increase in illnesses and accidents (Assunção & Almeida, 2003).

National and international studies on refrigerators present literary evidence focused on health, ergonomics, and work safety, which reports high rates of risk for occupational accidents and diseases amongst abattoir workers (Armstrong *et al.,* 1993; Bao *et al.,* 2001; Busnello & Dewes, 2013; Frost *et al.,* 1998; Heck, 2013; Juul-Kristernsen *et al.,* 2002; Musolin *et al.,* 2014; Sarda *et al.,* 2009; Sommerich *et al.,* 1993; Sundstrup *et al.,* 2013; Sundstrup *et al.,* 2014). Current national estimates for social welfare report that 23% of the refrigerator sector workforce is off work or awaiting court rulings on occupational accidents and related diseases (Brasil, 2016).

The highest incidence of injuries among abattoir workers occurs in the upper limbs as a result of business models based on un-automated industrial processes that require intense manual product handling and manipulation (Rossi, 2008). In addition, inside the refrigerators, the worker's hands feel great discomfort from directly contacting cold chicken parts whose temperatures may be below 10°C (depending on the sector).

The discomfort caused by the cold during abattoir activities is often circumvented by the individual use of extra layers of clothing under company uniforms. However, this does not usually happen with the extremities, especially for fingers and hands, where agility and precise motor skills (required to perform routine movements) are compromised by the use of gloves (Holmér, 1997).

Exposure to cold environments while performing abattoir tasks leads to body heat losses. This occurs in numerous sedentary work environments where the worker's bodies do not generate heat, thereby jeopardizing not only the worker's health, but also adversely affecting their comfort and productivity (Holmér, 1997). Excessive body heat loss and cooling is called hypothermia, and it occurs when the body temperature falls below 35ºC. Moreover, another consequence of exposure to cold, below tolerable limits, is discomfort followed by pain in the affected region (ISO 13732-3: 2005). These symptoms may worsen, depending on the exposure duration and the temperature drop, and the onset of diseases may occur if proper measures are not taken. Cold exposure-related diseases commonly cited in the medical literature are ulcerations, frostbite, Raynaud's phenomenon, cold hives, chilblains (Perniosis) and respiratory diseases among others (Salim, 2003).

Health and safety regulations only stipulate parameters and quantitative data to control environmental cold. Ordinance 210, which was made on 10/11/1998 by the Ministry of Agriculture and Supply of Brazil (and is mandatory for the meat processing industry), stipulates that cutting room temperatures cannot be higher than 12ºC, while poultry must be below 7°C (Brasil, 1998). Similarly, Regulation (EC) 853/2004 of the European Parliament and of the Council lays down specific hygiene rules for prepping, packing, and storing meat products, and for setting the ideal meat processing facility temperature to a range from 2°C to 7°C (Regulation (EC) No 853:2004). International Standards (e.g., ISO 15743) specify the use of a room air speed below 0.2 m/s, and a humidity of approximately 80%, where product and work surface temperatures should range between 3 and 4°C (down to -2°C when handling frozen meat) (ISO 15743: 2008). The international standard for the thermal environment ergonomics (BS 7915: 1998), however, characterizes cold environments as those with an air temperature below 12°C (BS 7915: 1998).

Common standards use obligatory quantitative data to parameterize temperatures and other variables (e.g., humidity) inside refrigerated work environments. Production models that fail to observe these standards should be interdicted until they meet the mandatory environmental guidelines. However, only the ISO 11079 standard sets control or limit values for temperatures that can be tolerated by workers (protected or otherwise) exposed to cold while in contact with materials, and/or cold products, and/or subject to ambient temperatures (ISO 11079: 2007).

Thermographic images can be used to detect and to monitor a worker's body surface temperature. Recognized by the American Medical Association (Hildebrandt *et al.,* 2010) since 1987, it has practical applications in various activities (Banderia *et al.,* 2014). The method is based on the detection of infrared radiation emitted by the skin and non-invasively analyzes skin temperature without exposure to any type of radiation (Banderia *et al.,* 2014). This technique registers, in real time, the surface temperature of the examined human body part.

An advantage of this technique as a control tool for the environmental cold is its ability to obtain quantitative information about the worker's body temperatures, and not just the work environment information or the worker's subjective perceptions.

It is very risky to measure and to estimate the temperature of a working environment based only on individual subjective parameters or, in some cases, on the lack of evidence for determining if the room's temperature meets the worker's requirements for comfort and health. This was confirmed by Ramos and group (Ramos *et al.,* 2015), who measured the hand temperatures of 227 meatpackers. Results showed that there were no statistically significant correlations between the finger temperatures of knife handlers and their subjective thermal perceptions of the work environment (Ramos *et al.,* 2015).

According to the statistical yearbook maintained by the Brazilian Institute of Geography and Statistics since 1997, the slaughter of chickens in Brazil during the 4th quarter of 2015 set a record with 1.51 billion slaughtered chickens (IBGE, 2016). This number directly demands an increased number of workers to meet production targets, which makes it necessary to invest in more effective methods to control the risks associated with such tasks, namely the environmental cold, to prevent an escalation of accidents and occupational diseases.

This study's aim is, within this context, to evaluate the use of thermal imaging as a health risk control tool. To do so, we analyzed skin temperature variations on six body parts of workers exposed to cold in air conditioned and artificially controlled work environments.

MATERIAL AND METHODS

To gauge the results of thermal imaging as a risk control tool caused by exposure to cold in air conditioned and artificially controlled work environments, we conducted a thermographic assessment of six body parts of workers from two chicken processing sectors (cut and seasoning) of a slaughterhouse located in the Santa Catarina region. The company's current staff count is 1298 employees, which is divided into two slaughter shifts, and a third shift dedicated to preventive maintenance, and to cleaning the machinery and equipment. The company slaughters an average of 90.000 birds daily: 48.000 birds during the first shift, and 42.000 birds during the second shift.

The research was conducted during the first two shifts only due to their similarities in terms of environmental conditions, product and equipment handling, and the need to meet Decree 210, which was made on 10/11/1998 by the Ministry of Agriculture and Supply of Brazil, which establishes minimum and maximum temperatures for products of animal origin, as well as their handling rooms.

A production working day is 8 hours and 48 min long, with a 60 min meal break and another 60 min break for psycho-physiological recovery, which is split into three segments (20 min each), as dictated by the NR-36-Security and Health at Work for Slaughtering, Meat and Derivatives Processing Companies(NR 36, 2014).

A working day for the studied subjects, both in the cut and seasoning sectors, begins at 06:00 a.m. with the first pause occurring between 07:20 a.m. to 07:40 a.m., the second pause occurring from 09:20 a.m. to 09:40 a.m., a lunch break occurring from 11:40 a.m. until 12:40 a.m., the third break occurring between 14:20 p.m. and 14:40 p.m., and the work day ends at 15:48 p.m.

The study was conducted in a room with an average temperature of 23.2°C, which was measured with a thermal stress measurer (Instrutherm, model TGD-300).

A typical work day in both sectors consists of picking up and handling chicken pieces with one hand and facilitating knife cuts with the other hand.

Body part temperatures were measured with a thermal imager, the Flir E40 model, with the following calibration parameters: 0.98 emissivity (human body), 20°C reflected temperature, and an 80% relative humidity. As shown in Figure 1, the equipment was installed on a tripod that is 85cm tall and 100cm away from a tecnil plate that was used as a hand screen. The plate is 30cm by 25cm wide.

Figure 1 – Image collection apparatus: Equipment and worker positions

As shown in Figure 1, each participant was led from the production line to the evaluation room for temperature measurements. The course from the workstation to the evaluation room took 25 seconds. During the course, the workers were instructed not to touch their hands on any part of their body, and that they could not remove their gloves. Before the measurement, the protective gloves were removed, the sleeves were raised and the worker's hands were positioned in front of the tecnil screen to register the imagery. Images were obtained from the workers after they were continuously exposed to continuous cold for 1 h and 40 min. This occurred before the second psycho-physiological break so the maximum uninterrupted cold that workers were subjected to during a working day could be registered.

This research is a pilot study. The company made available a total of 20 women – 10 from the chicken sector (specific breast cut per the product specification), and 10 from the seasoning industry (specific cut and weighing of seasoned chicken parts per product specification) –where 50% were cut workers and 50%

were from the seasoning sector. The sole prerequisite was that their sector experience exceeded one month. Only women were selected given the inexistence of men working in any of those two sectors during the survey period. On average, 41% of the company staff (which totaled 532 workers, 59% were female, were divided into two shifts) currently works in rooms exposed to the cold. The exposure to cold varies according to the location and the process; according to the rooms evaluated, there were rooms with exposure to positive and negative temperatures.

The images obtained were processed using the QuickReport software, version 5.4.15351.1001, which is licensed by Flir Systems AB through Microsoft Licensing. The software provided minimum, maximum, and average temperatures for each selected body site. The statistical analysis of the results focused on the average temperatures for the first distal phalanx of the second finger on each hand, the center of the hands, and the region close to the wrist as indicated in Figure 2 by numbers 1, 2, 3, 4, 5, and 6 respectively. These regions are located on the dorsal sides of both hands.

The six body sites that were selected are the fingers, the center of the hand, and the wrists of both hands, where the sites were chosen based on ISO 11079: 2007, the "Ergonomics of the thermal environment" which does not determine specific points to be evaluated for exposures to localized cold, but it does recommend frequent control of finger temperatures, and it suggests that temperatures should be above 24°C for the preservation and proper functioning of the hands. ISO 11079: 2007 also specified that the amount of knowledge regarding responses to local cooling is insufficient for the development of a single assessment method, and that research on the subject should be encouraged (ISO 11079: 2007).

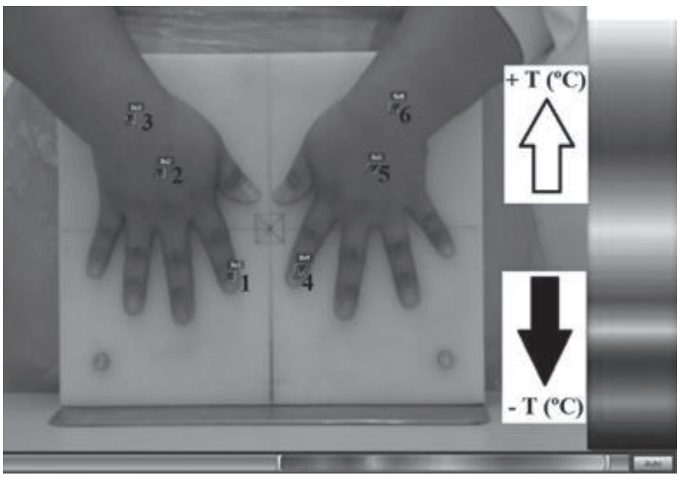

Figure 2 – Images of the analyzed body parts

The data analysis considers the average temperature of each body part, which differs from the hand holding the knife to the one holding the product to be cut. This differentiation is important because of the temperature differences between the knife and the product. Another factor to consider is the use of different glove types on different hands and between workers in each sector.

Staff in the cutting sector wore latex gloves overlaid with steel mesh gloves when they handled the product, and cotton gloves overlaid with latex gloves on the hand holding the knife. Employees in the seasoning sector wore anti-cut gloves overlaid with latex gloves on the hand handling the product, and cotton gloves overlaid with latex gloves on one hand holding the knife. This study did not consider the thermal resistance indices of these gloves and their combinations, because the goal of this study was not to ensure that the gloves met the thermal comfort requirements for these activities.

Thermographic image maps of hand temperature distributions (particularly in the regions of interest) displayed a spectrum of colors and values that can be calibrated depending on the model of the equipment used. The scale on the right side of Figure 2 maps low temperatures as black (approximately 10°C), and higher temperatures as white (circa 32°C). This information provides the minimum, maximum, and the average temperature values for each body part that was assessed.

The interpretation of this data employed descriptive statistics that calculated the frequency, relative frequency, and the percentage of noun. To compare the result averages, we resorted to F-tests for the variance analysis.

The results were analyzed based on the temperature ranges adapted from Lehmuskallio *et al.,* (2002), where the temperature intervals indicate the following: 36–34°C denotes thermal comfort, 33.9–29°C signifies a thermally neutral condition, 28.9–25°C indicates thermal discomfort (chilly), 24.9–18°C produces a feeling of discomfort (cold), 17.9–12°C produces a sensation of pain caused by cold, 11.9–8°C induces pain sensations and tingling (the gradual loss of tactile perception) and <8°C causes pain and freezing sensations (Lehmuskallio *et al.,* 2002).

To measure the surface temperature of the knife's handle and the product handled by each worker, we used a Minipa infrared digital thermometer (model MT-350). The air speed inside the rooms was calculated using an Instrutherm thermo-hygro-anemometer (model THAR-200).

The study was permitted by the company's legal representative, who provided access to the facilities to conduct the experiments. The participating staff freely consented to the research protocol, which was submitted and approved by the Ethics Committee at the Federal University of Santa Catarina, and fulfilled all legal recommendations in Brazil. Anonymity and the confidentiality of information were maintained in the data records.

RESULTS

The measurements made in the work environment (the temperature, relative humidity, and the air speed), the knife handle temperature, and the temperature of the products handled are described first. These factors can directly influence the temperatures obtained from the worker's body parts during work hours, which are presented below.

In both sectors, the average room temperature was 11.2°C, the air speed was 0.26 m/s, and the relative humidity was 80%. The average temperature of the handled products was 4.4°C for seasoned chicken cuts, and 4.9°C for trimmed breast cuts. The average knife cable temperature was 9.0°C in the seasoning sector and 9.2°C in the trimming sector.

The colors in the thermographic image in Figure 3 show that there were no visible temperature differences between the hand handling the knife and the hand holding the product. These findings were consistent for all workers in both sectors. You can see a difference in the color tones. However, these results need to be evaluated statistically.

The color spectrum in the thermographic image shows that the fingers experienced the lowest temperatures (represented by almost black, dark violet tones), and temperatures at the center of the hands and wrists (represented by red) are higher than the temperatures measured at the fingers. Descriptive statistics for the data are presented below so that a quantitative analysis of the results could be made as shown in Figure 3.

Figure 3 – Thermographic image of a worker's hands

The data presented in Table 1 refers to the average results obtained from the thermographic analysis; which was performed on the body parts (fingers, hands, and wrists) of 20 employees that covered both sides of the upper limbs – one holding the knife and the other that maneuvered the product.

The data was grouped by scale level based on recommendations by Lehmuskallio *et al.* (2002), which began with the lower temperatures (8°C), and ended with temperatures above 36°C.

The results shown in Table 1 indicate that the most frequent finger temperatures were in the range of 12.0°C to 17.9°C, which represented 60% of knife-holding fingers and 65% of product-handling fingers.

For the temperatures measured in the center of the hands, the more representative results varied between 25°C to 28.9°C, and accounted for 55% of the centers of knife-holding hands and 65% of the centers of product-handling hands. The same scale prevailed when evaluating the wrists. The higher temperatures ranged from 25°C to 28.9°C, which belonged to 55%

Table 1 – Results: temperature range

Scale (°C)	Finger holding the knife			Finger holding the Product			Hand center holding the knife			Hand center holding the Product			Hand wrist holding the knife			Hand wrist holding the Product		
	F	F.R.	P%	F	F.R.	P%	F	F.R.	P%	F	F.R.	P%	F	F.R.	P%	F	F.R.	P%
<8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 – 11.9	0	0	0	1	0.05	5	0	0	0	0	0	0	0	0	0	0	0	0
12 – 17.9	12	0.60	60	13	0.65	65	0	0	0	0	0	0	0	0	0	0	0	0
18 – 24.9	7	0.35	35	4	0.20	20	3	0.15	15	4	0.20	20	2	0.10	10	2	0.10	10
25 – 28.9	1	0.05	5	2	0.10	10	11	0.55	55	13	0.65	65	11	0.55	55	12	0.60	60
29 – 33.9	0	0	0	0	0	0	6	0.30	30	3	0.15	15	7	0.35	35	6	0.30	30
34 – 36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	20	1.00	100	20	1.00	100	20	1.00	100	20	1.00	100	20	1.00	100	20	1.00	100

Nomenclatures: F.: frequency; F.R.: relative frequency; P%: percentage.

of the knife-holding wrists and 60% of the product-handling wrists.

The data in Table 2 shows the results of the statistical analysis that was conducted to verify the influence of the gear used in either hand (gloves, knife, and the product handled) on the temperature of the body parts studied.

Results for the employees from both sectors showed that the values of the F-statistics were below the critical F value. Thus, the values listed in Table 2 are acceptable without significant differences between the average temperatures of the fingers, hands, and wrists taken from either hand (the knife holding or the product-handling hand).

Table 2 – Results: Statistical analysis of the average ratings for the body parts analyzed

Sector	Studied body part	Number of Samples	Average temperature (ºC)	Variance	Statistical F-test	critical F
Cut	Finger/Hand/Knife	10	17.07	8.20	0.34	4.41
	Finger/Hand/Product	10	18.14	25.72		
Seasoning	Finger/Hand/Knife	10	16.86	16.82	0.10	4.41
	Finger/Hand/Product	10	17.49	23.79		
Cut	Center/Hand/Knife	10	27.67	6.97	0.09	4.41
	Center/Hand/Product	10	28.00	5.77		
Seasoning	Center/Hand/Knife	10	27.27	5.64	2.69	4.41
	Center/Hand/Product	10	25.54	5.49		
Cut	Wrist/Hand/Knife	10	28.72	5.32	0.20	4.41
	Wrist /Hand/Product	10	29.18	5.27		
Seasoning	Wrist/Hand/Knife	10	28.54	4.24	2.25	4.41
	Wrist/Hand/Product	10	27.17	4.10		

DISCUSSION

Despite the temperature of the product being lower than the temperature of the knife's handle, this difference did not actually impact the results of temperature distribution of the hands as illustrated in the thermographic image shown in Figure 3. This effect was probably suppressed by the different gloves used on both hands, and/or due to thermal stabilization resulting from the exposure to low room temperatures, and the materials used and handled.

The results of the evaluated finger temperatures represent, according to Lehmuskallio *et al.* (2002) and among the evaluated workers, 60% of the knife-holding fingers and 65% of the product-holding fingers. There are workers experiencing discomfort and pain caused by exposure to the cold.

The results reveal that 5% of the worker's fingers on the hand holding the knife experienced temperatures that ranged from 8 to 11.9 °C. In this temperature range, the sensation may be experienced as pain and/or tingling with a possible loss of tactile perception.

These finger measurements were supported by the findings of Ilmarinen & Tammela (1990), who noted that workers without adequate personal protective equipment (PPE), e.g., for hand protection, inside a cold slaughterhouse cutting room (with an average temperature of 10°C, which is similar to our study) presented finger temperatures between 17 and 12°C. According to researchers, such conditions jeopardize the body's thermal balance, thereby increasing the risk of accidents due to cool and numb fingers, which lead to stiff fingers and hands, the loss of manual dexterity, and to reduced muscular strength.

Workers in this study, unlike those in the work of Ilmarinen & Tammela (1990), wore cold protective gloves provided by the company. However, the finger temperatures of workers in our study were close to those for the workers in the study of Ilmarinen & Tammela (1990). This result indicates that the use of protective gloves does not prevent workers from suffering from health problems and accidents identical to those cited in the research by Ilmarinen & Tammela (1990).

The lower temperatures (defined as the previously reported critical findings) were detected in the fingers on both hands of workers in both sectors. These conditions occurred for two reasons. Namely, the finger's prolonged contact with objects at temperatures below 10°C during work activities, and from their fingers possessing a smaller mass surface that increased the heat loss rates, and lowered the blood flow in relation to the other evaluated body regions (Williamson *et al.,* 1984).

ISO 11079: 2007 recommends controlling the finger temperature in the workplace, and keeping temperatures above 24°C to satisfactory preserve manual function. In this study, the fingers on both hands were considered, where only 10% of the product-holding hands and 5% of the knife-holding hands revealed temperatures that was recommended by ISO 11079: 2007. Holmér's (1999) study stated that finger temperatures below the comfort level can be occasionally acceptable but this situation will lower the strength, dexterity, and the coordination, as well as increase the number of complaints related to pain sensations.

The temperature at the center of the hands presented average variations between 28.00 and 25.54°C, which comply with ISO 11079: 2007 regarding satisfactory hand function. However, the discomfort caused by the cold felt by workers suggests that the adopted parameters of scale still need improvement.

The results of the wrist assessment (with respect to the hand holding the product) showed a mean temperature of 29.18°C for the workers in the cut sector; this temperature was thermally comfortable. The remaining wrist results revealed some discomfort caused by the cooled body part.

As soon as the risk potential was detected (i.e., cold fingers caused by continuous contact with cold objects, and owing to exposure to low temperatures in air-conditioned environments), as in this case, a course of action must be followed to control it and to guarantee the health of the workers.

Although results may suggest that fingers are the most affected region, it is important to note that environments with temperatures close to 10°C can jeopardize a worker's health. Some health threats in this industry have been previously addressed in other studies. A research by Thetkathuek *et al.* (2015) examined 497 workers exposed to cold food processing industries in Thailand, which identified workers that suffered from muscular pain, respiratory problems, cooled finger conditions, and cardiovascular symptoms.

The study by Kaminski *et al.* (1997) is also referred to as an example of causal links to health risks. The data therein, which was collected during 1987–1988 from 1474 French workers at 17 poultry slaughterhouses and 6 canneries, demonstrated that it is possible to detect risk factors related to Raynaud's phenomenon among a population of men and women exposed to cold without vibration (Kaminski *et al.,* 1997).

Another relevant point is that, in the absence of a quantitative assessment (where actions are taken based on qualitative and subjective data), occupational diseases cited as resulting from uncontrolled exposure to cold ulcerations – such as frostbite, Raynaud's phenomenon, cold hives, chilblains (Perniosis), hypothermia, and respiratory diseases (Salim, 2003) – cease to be considered as work-related owing to the lack of information on individual body temperatures. Consequently, the cold environments, at their origin, are no longer targeted by medical, work safety, ergonomic and occupational hygiene directives. The failure to perceive risk usually results in inaction and a lack of attention to and investment in the improvement of such facilities.

In some cases, symptoms do not occur immediately after the exposure to low temperatures, which makes it more difficult to control the health of workers exposed to the cold. This makes it crucial to determine the thermal conditions that staff is immersed in at their work place. Furthermore, the divergence of individual physiological and metabolic capacities cannot be overlooked, and results from some people having a greater resistance to cold than other people. This factor should be considered when equipping workers with PPE. All workers in this study, irrespective of their sector, were provided with identical glove sets (using the same risk resistance specifications, but only with different sizes); however, they showed differences in their measured skin temperatures.

When it comes to occupational health, the focus should be on the conditions endured by the workers at their workplace. Regarding the cold, it is essential to verify the environment's impact on a worker's body temperature, which can be determined by thermographic evaluation. The latter can help implement control measures, particularly for the improvement of personnel protective kits. When this is not viable, the valuation model could at least provide valuable information regarding the adjustment of pause times to allow for thermal recovery, which also depends on the environmental conditions and on the activities performed.

This study detected workers in distress and even in pain when exposed to harmful health conditions. Alternatives must be sought to guarantee their thermal comfort. According to Fanger (1970), thermal comfort is achieved by calculating the level of clothing thermal insulation required by activity level and the type of work. A natural conclusion for this research, where the analyzed business model predetermines both the room and product temperatures with an inflexible and tightly controlled scale, is that the improvement of thermal insulation can only be attained through proper attire. In this case, the PPE used was ineffective against cold as it did not meet the minimum limits of thermal comfort for the worker's fingers. This fact suggests that the company should adopt different equipment (that is tested and approved prior to use) for air-conditioned environments. In research conducted by Nielsen (1986), where a worker's fingers and hands were exposed to cold under similar conditions, several options were recommended, such as thick gloves with extra finger insulation, or gloves with small insulating buttons in the palm region to reduce the contact surface with cold objects while also improving the worker's grips on the products, which thereby reduced the need for strength (Nielsen, 1986).

The need to implement the use of effective protection against cold is made even more relevant through the conflict between food hygiene legislation (that sets minimum and maximum temperatures for rooms and products) and the rating scale adopted from ISO 11079: 2007, which sets the minimum comfort temperatures that control a worker's health risks. The obtained data shows that room temperatures and the temperatures of handled products currently meet national and international standards, namely, Ordinance 210 10/11/1998 from the Ministry of Agriculture and Supply of Brazil, which, despite being mandatory for food handling, focuses exclusively on facilities and product, thus overlooking the staff's working conditions.

The data extracted from this study's infrared thermographic evaluation manifests the need for an improved business model. Its production and staff makes it essential to establish measurable temperature limits to which a worker's body is exposed.

CONCLUSIONS

The Brazilian legislation lacks work safety parameters for occupational cold exposure. This hinders the actions of companies and confounds the judgment of medical and work-safety professionals with regards to ensuring adequate work conditions in cold environments.

Thermography makes it possible to improve the control of the risks of working in cold temperatures, by quantifying these temperatures in the actual working conditions by means that are not qualitative or subjective. Environmental parameters, the equipment used, and the products handled relate both to the production methods and to the product's hygienic and sanitary conditions. However, the body part temperatures did not always meet the control measures of risks caused by the cold. Temperatures obtained from the fingers of the workers from both sectors revealed possible discomfort, pain, loss of performance, functional imbalance, discomfort caused by the cold, tingling, accidents, and a possible endurance of conditions leading to cold exposure related diseases. It is therefore vital to invest in easily implementable parameters, namely, personal protective equipment to ease the discomfort and pain caused by cold, and/or to introduce additional breaks for thermal recovery.

It can be concluded that the use of thermography for the analysis and the evaluation of surface skin temperatures presents an efficient model for quantifying the risks of working in cold temperatures, and to provide information to control occupational health risks posed by air-conditioned and artificially controlled environments.

Infrared thermography has been successfully applied to a number of areas, such as health and safety-related applications. A practical application of thermography encompasses the control of the risks of working in cold temperatures for workers exposed to low-temperature environments by allowing measurements of the worker's skin temperatures. The decision to control the risks of working in cold temperatures are based on quantitative data.

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