Case report

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Meat quality, biosecurity, and animal welfare: consequences of an inefficient inspection

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ABSTRACT

In livestock, biosecurity, animal welfare and meat quality have a synergetic effect on the final product. To meet minimal safety and humane production, it is necessary to consider biosecurity risks and procedures to mitigate animal welfare problems. Following guidelines to achieve it, the meat quality improves consequently. Here we tested two parameters regarding the meat quality of beef cattle to understand how the poor inspection affects the quality of the final product. Therefore, 12 samples of the *longissimus dorsi* muscle were evaluated from different butcheries, using fresh meat recently received by the supplier. There were no sanitary inspection records related to the sampled meat. The results showed a large percentage of PSE (pale, soft, and exudative) and DFD (dark, firm, and dry) meats. Given the pH and color values, it is concluded that the slaughtering was not carried out properly. Hence, technological defects in the meat were observed, making it inappropriate for consumption. We concluded that inefficient pre-slaughter handling is compromising animal welfare, increasing the biosecurity risk, and impairing the quality of the final product. We argue that these problems not only decrease the sustainability of livestock systems, but also compromises human health. Currently, livestock plays an important role in global environmental concerns, such as climate change, land degradation, water pollution and biodiversity loss. Then, it is needed to reduce the waste of such products.

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1. Introduction

Biosecurity, animal welfare and meat quality are variables inexorably interdependent. To meet minimal safety and humane livestock systems, it is necessary to consider biosecurity risks, as well as procedures to mitigate animal welfare problems.

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A sustainable system, taking into account biosecurity and animal welfare will provide better quality for the meat. Furthermore, for being considered sustainable, the system should be acceptable in the present, as well as its consequences for the future, regarding resource availability, effects of functioning and morality of action (1).

This concern increases because livestock is one of the factors which most causes land transformation and widespread environmental pressures in many parts of the world (2-4). Currently, livestock plays an important role in global environmental concerns, such as climate change, land degradation, water pollution and biodiversity loss. Additionally, the increased consumption of animal source food caused by human population growth has been growing, and it is expected to continue growing (3). Livestock systems emit 8-18% of greenhouse gases and use 25-32% of global fresh water (3). In this sense, it became extremely necessary to increase sustainability, reduce the losses and impacts per unit of animal product, especially in the field where we already have the knowledge and guidelines available.

Following this concern, an important meat quality parameter to be assessed is pH. Muscle pH just after slaughter is usually around 7.0, and the pH can influence color, tenderness, water retention capacity. If shortly after slaughter (45 min) the pH value drops rapidly below 6.0 with an ultimate value of 5.3, the meat may become pale, flabby and with low water retention capacity, being then characterized as PSE (5). If the final pH remains high, above 6.0, the meat has a technological defect called DFD, which is mainly characterized by dark, hard, and dry meat (5).

Regarding biosecurity, meat with technological defects has a short shelf life, unlike meat with a good quality profile. Moreover, its pH of around 6.0 favors microbial growth, decreasing its shelf life (6). Most of the technological defects found in meat are mainly from non-inspected meat products. Even if there is no apparent abnormality, the consumer is exposed to several health risks. There have been several outbreaks of foodborne disease caused by *Escherichia coli*, *Salmonella spp.*, *Campylobacter jejuni*, *Yersinia enterocolitica, Listeria monocytogenes* (7) and *Staphylococcus aureus* (8). Additionally, parasites such as *Trichinella spp.*, *Taenia saginata* and *Toxoplasma gondii* should also be taken into account for risk-based surveillance for meat-borne diseases (9). Nowadays, the global burden of food-borne disease is too heavy, especially among children under five years of age (10). Post-mortem examination plays an important role in mitigating the risks and harm of meat-borne disease such as tuberculosis (11). Surveillance at slaughterhouses is an important tool for the prevention of meat-borne disease and biosafety.

A satisfactory inspection at slaughterhouses is necessary to guarantee the biosafety of livestock products.

Furthermore, the animal welfare guidelines are relevant not only for moral concerns, but also to improve the meat quality. Welfare is a term that refers to animals, including man. In recent years, welfare has become established as one of various criteria used to decide on whether a system is sustainable, focusing on the acceptance by the society. The welfare of an individual is defined as its state regarding its attempts to deal with its environment (12). A animal welfare must be controlled during all stages in the pre-slaughter management, not only to guarantee high-quality meat but also because Brazil is a signatory of the World Organization for Animal Health. When these procedures are poorly executed, the glycosidic reserve falls due to excessive stress, leading to defects of technological origin, such as DFD and PSE. Furthermore, chronic stress is known to decrease the immune system, which can increase the biosecurity risks.

Here we tested two parameters regarding meat quality to understand how poor inspection affects the quality of the final product. We extended the discussion of this case study, due to the urgent need for a holistic approach in the way we are dealing with livestock products, inspection, meat quality, biosecurity, and animal welfare since all these factors are intrinsically connected with sustainability.

Case presentation

The meat samples of the *longissimus dorsi* muscle were collected in 12 commercial establishments in the city of Bom Jesus, Piauí state, Brazil, from November 1st to 15th, 2019. As a pre-established factor, the meat would only be analyzed for pH and color if they were fresh and recently received by the supplier, preferably on the same day. Thus, 12 meat samples were assessed, and the analyzes were carried out in triplicates.

For the analysis of the samples, approximately 100 g of meat with approximately 3 cm in thickness were collected and analyzed for pH and color. The initial pH was measured in the center of the *longissimus dorsi* muscle, approximately 15 min after purchase, using a digital pH meter (Figure 1, Testo, model 205). The meat color was measured in the same sample using a colorimeter (Figure 2, Minolta Chroma Meter CR-300). The colorimeter has an 8 mm diameter measurement area and uses an illuminant D65 and 10° standard observer. Were evaluated the lightness (L*), redness (a*), and yellowness (b*), and the aspects were assessed by the CIE L* a* b* color system (CIE, 2004). The measurements were made at three different points on the sample surface, taking the mean as the determined value. After refrigeration (4°C) of the meat samples (12 h), the ultimate pH and color were measured at the same place above mentioned.

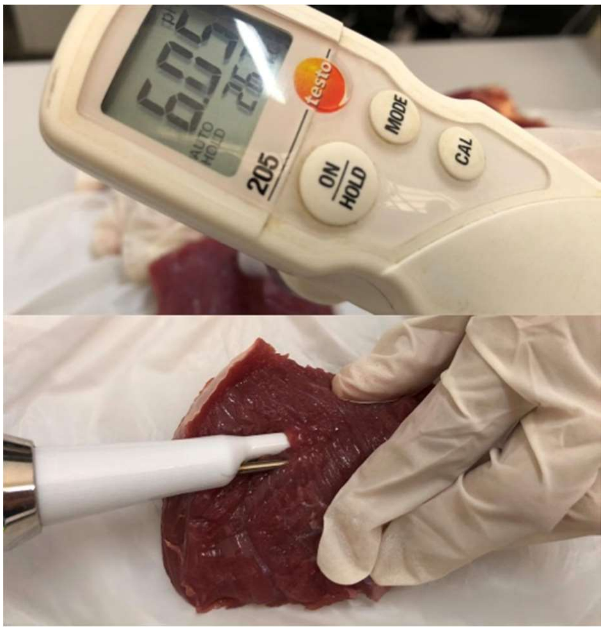

Figure 1. Testo 205 pH meter (Testo AG, Lenzkirch, Germany).

Figure 2. Minolta CR portable colorimeter (Chroma Meter CR-300, Konica Minolta Sensing Americas Inc., Ramsey, NJ).

The evaluation of the pH and the color of fresh meat from butcheries led to pH results from 5.33 to 6.8 (Table 1), which are correspondent to PSE and DFD meat, respectively (5).

Table 1. pH and color values of *longissimus dorsi* muscle from commercial establishments in Bom Jesus-PI, Brazil

Item	pH	L*	a*	b*
Average	5.72	37.73	13.61	12.35
Lowest pH	5.33	39.58	14.06	13.13
Highest pH	6.80	31.37	9.17	9.89
CV (%)	5.77	11.57	23.14	22.27

Despite the average pH being within the reference values, there was a high occurrence of meat with pH outside the reference values (Figure 3). Of the 12 meats analyzed, 40% had pH > 5.8, 38% pH < 5.5 and only 21% had pH within the reference values > 5.5 to < 5.8. Thus, approximately 78% of the meats analyzed had a pH outside the reference values, thus suggesting technological defects.

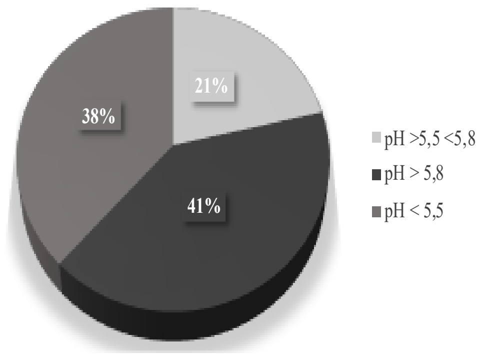

Figure 3. Percentage of pH of *longissimus dorsi* muscle in commercial establishments in Bom Jesus-PI, Brazil.

Regarding color measurements, L* values between 33.2 and 41.0, a* between 11.1 and 23.6 and b* between 6.1 and 11.3, are considered normal. The averages of the L* and a* values observed (Table 1) are within the reference values, but the b* values were higher, showing PSE meats, which are meats characterized by pale color. The b* showed an intense color for the yellow index and less evident for the red index, that is, showing a yellow flesh (13).

In one of the samples, the arrival of a recently slaughtered animal carcass was found, which was at room temperature (28.6ºC). Thus, a sample of *longissimus dorsi* muscle was collected and analyzed at the time of purchase and 12 h after the first analysis, so it was kept stored cooled at a temperature of 4 to 8°C until the analysis.

According to the pH value of 6.80, color (L * 31.37 to * 9.17 and b * 9.89) and the temperature of the meat (28.6° C) characterizing an elevated temperature for commercialization. It is assumed that the animal would have been slaughtered a few hour before purchase. Hence, the rigor mortis period that varies between 12 and 24 h. after slaughter was not followed, including the carcass cooling (6.13; Figure 4). This type of meat suggests the technological defect DFD, which is characterized by a dark, hard, and dry meat.

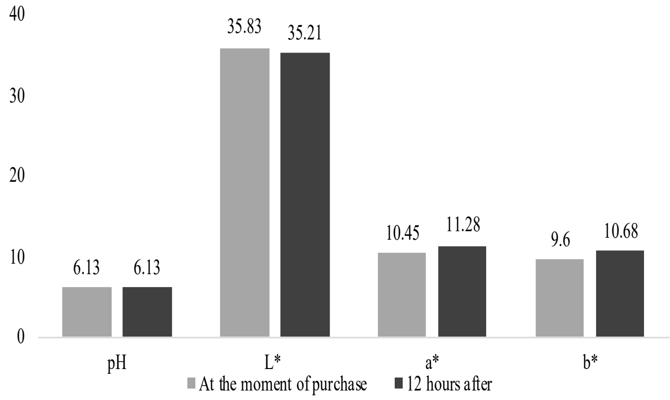

Figure 4. pH and color of *longissimus dorsi* from the moment of purchase until 12 h after the purchase of a specific sample.

Discussion

We demonstrated that most of the slaughtered animals presented indicators of questionable meat quality. Additionally, meat quality indicators are related to chronic stress, which is directly related to immunosuppression, increasing the risk of biosecurity. The absence of inspection also compromises the quality of the final product sold. The absence or poor inspection is directly related to biosecurity risks, compromised animal welfare and poor meat quality. All these factors are related to the sustainability of the system.

Chronic stress before slaughter leads to technical defects in the meat and makes it dark, hard, and dry (DFD). In this case the decrease in the pH of the meat is lower than the normal, as the muscle contains a low concentration of glycogen making the meat drier and darker, due to its greater capacity for water retention. As these meats have higher pH than meats produced under normal conditions, they are more susceptible to microbial proliferation and consequently have a shorter shelf life (6). Meats with a pH below 5.5 turn into PSE meats, which are observed in animals that suffered acute stress just before slaughter. The main cause of the development of the meat condition PSE is an accelerated decomposition of post-mortem glycogen that generates a high concentration of lactic acid, which in turn dramatically decreases the muscle pH, while the muscle temperature is still high in ambient or physiological conditions, leading to a protein denaturation process compromising the functional properties of the meat (5).

To confirm the occurrence of DFD meat, we evaluated the newly purchased meat by the butcher. Its pH remained at the same value (6.13) after 12 h cooling (Figure 4). In the samples, there was no reduction in the pH of the meat. Meat has a high pH due to insufficient glycogen reserves at the time of slaughter, caused by chronic stress before slaughter, depleting glycogen reserves, producing lactic acid that is responsible for the decrease in post-mortem pH, with pH values > 6.0 where there was no reduction. Meat showing DFD is related to chronic stress before slaughter, which is related to inadequate handling, such as at the time of transport, animals unloading at the slaughterhouse, waiting for corral, desensitization, and bleeding, causing physical exhaustion of the animal (14).

Therefore, as in the city there is no slaughterhouse with official inspection services, these animals are informally slaughtered without good transport and slaughter practices.

There has been informal meat trade in Brazil, and we highlight the year 2018, in which 77.93% of the animals slaughtered in the country were under some type of inspection (Federal, State, and Municipal). However, 22.17% of the animals were slaughtered without any official inspection, that is, 9.8 million head of cattle were slaughtered illegally (15).

Once livestock is one of the factors that is impacting the environment globally, it is needed to reduce the waste of such products. Livestock is a significant contributor to the main challenges of the Anthropocene, which includes climate changes (16). To increase efficiency, it is necessary to reduce the losses, especially in cattle, since its productivity causes a huge impact, and its consumption is only accessible to a minority. Most of the land is being used by extensive, grazing-based ruminant systems. Grazing-based systems contribute very little to the human food supply globally, representing less than 1% of its edible energy (3). However, these systems have critical contributions to livelihoods and sociocultural interactions, and above all, environmental impact. Additionally, the consequences of environmental impact are impacting human beings across the globe, including the ones that are not having access to these products. In this case study, it is clear the food energy waste is caused by the compromised meat quality and the potential costs of diseases in humans.

Regarding compromised animal welfare, it not only violates the guidelines of the World Organization for Animal Health, but also instruments with legislative power in Brazil (17). Moreover, there are some resolutions, ordinances, and normative instructions from institutions such as the Ministry of Agriculture, Livestock and Supply, the Federal Council of Veterinary Medicine, and the National Traffic Council, providing guidelines about animal welfare. As demonstrated before, meat quality can be a tool as an indicator of animal welfare.

Concerning biosecurity, the poor meat quality compromises the safety of the products. A similar study identified the presence of fecal coliform, mesophytic bacteria and, *Staphylococcus* sp in 100% of the stores assessed (18). In this sense, the data demonstrated that the products available in markets were unfit for consumption (18). By increasing biosecurity, the use of antimicrobials reduces (19), impacting positively the economy of the system, as well as increasing the sustainability. In a study investigating pig farms, it was clear the relationship with welfare problems, such as stocking density, air quality, poor cleanliness, with an increased number of antimicrobial treatments due to respiratory diseases (19). Moreover, there is an urgent need to reduce antimicrobial use, and this is only possible aligning with other strategies, such as improving animal welfare. One of the greatest current problems is the rapid development of antibiotic resistance since some diseases are becoming untreatable (1).

Globally, we are facing critical challenges that will need international-based solutions. Challenges like antibiotics used in livestock, bacterial resistance, environmental impact, and climate changes, need more input data and multidisciplinary experts to mitigate there effects. Planetary guidelines are necessary to protect human health, once there are no borders to infectious diseases and consequences of environmental impact.

The intense production of animals in farms can also change the microorganisms and trigger new pandemics. The way one society deals with its food, can globally impact the health, and economy of the world. It is necessary to understand how to innovate for driving transformations in the current food system (20). However, the case study showed that some parts of Brazil, and probably in other countries, should face problems even more ordinary, such as inspection of meat. It is time to change some practices, starting from basic well-established protocols, such as inspection on slaughterhouses.

Conclusion

Based on the indicators of meat quality, we concluded that the deficient or absent inspection compromises animal welfare, increases the biosecurity risk, and impairs the quality of the final product. Once livestock is one of the major causes of environmental impact, it is necessary to have the basic guidelines in place and being inspected in several steps of the production. Based on this, there is an urgent need for more sustainable practices, which include a holistic approach.

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