SISTEMA ESPECIALISTA NO AUXÍLIO AO DIAGNÓSTICO DAS CAUSAS DE CONTUSÕES EM FRANGOS

Marco Antonio Maraia Vila, (M.Sc. in Mechanical Engineering) E-mail: marco.villa@posgrad.ufsc.br
Rogério Augusto Antunes Pereira (B.Sc. in Mechanical Engineering) E-mail: rogerio.antunes@posgrad.ufsc.br
Jonny Carlos da Silva (Ph.D. in Mechanical Engineering and Full Professor at the Department of Mechanical Engineering-UFSC) E-mail: jonny.silva@ufsc.br

Resumo: Em 2017 o Brasil se tornou o maior país exportador de carne de frango contribuindo com 24,88% de toda a carne exportada. Com a evolução e destaque da avicultura brasileira no cenário mundial, o maior desafio das indústrias avícolas é manter a qualidade das carcaças, já que o elevado número de condenações representa significativas perdas no setor. Um problema comumente encontrado neste tipo de indústria é a ocorrência de contusões em frangos de corte decorrentes de uma diversidade de causas devido a não-conformidades em processos de pré-abate. As alterações na pele são especialmente consideradas durante a análise visual ao abate e podem resultar na condenação parcial (ocorre o descarte para o consumo humano de partes afetadas da carcaça do frango), ou condenação total (ocorre o descarte da carcaça em sua totalidade). Neste artigo, foi desenvolvido um sistema especialista (SE) utilizando o software CLIPS para auxiliar profissionais inexperientes no diagnóstico de hematomas em carcaças de frango. Um sistema baseado em regras (Se – Então) foi utilizado para realizar o processo de diagnóstico. O SE auxiliou na detecção das causas geradoras da contusão e na tomada de decisão dentro da cadeia produtiva. Como saída do sistema um relatório é gerado onde é apontado em que etapa do processo a contusão ocorreu e o que deve ser feito para se evitar problemas semelhantes.

Palavras-chave: Protótipo de Sistema Especialista. Diagnóstico. Aves. Contusão. Hematoma.

EXPERT SYSTEM TO ASSIST ROOT CAUSES DIAGNOSTICS IN POULTRY BRUISES

Abstract: In the year of 2017, Brazil became the largest chicken meat exporting country contributing with 24.88% of all exported meat. With the evolution and prominence of Brazilian poultry in the world scenario, the biggest challenge for poultry industries is to maintain the quality of carcasses, since there is a high number of losses in the sector. A problem commonly encountered in this type of industry is the occurrence of bruising in broilers due to a variety of causes due to non-conformities in pre-slaughter processes. Skin changes are especially considered during visual slaughter analysis and may result in either partial condemnation (disposal of affected parts of the chicken carcass for human consumption) or total condemnation (complete carcass disposal). In this paper, an Expert System Prototype (ESP) was developed to assist inexperienced professionals in diagnosing bruises in chicken carcasses. The prototype assisted in detecting the causes that generate a bruise and in decision making within the production chain. As a system output, a report is generated to point out in which stage of the process the bruise occurred and what should be done to avoid similar problems.

Keywords: Expert System Prototype. Diagnostics. Poultry. Bruise. Hematoma.

1. Introduction

The production growth of chicken meat in Brazil in the last decade increased by 3.8%, from approximately 10 million tons in 2009, to around 13.5 million tons in 2017. Thus, Brazil occupied the first place in the ranking of exporting countries in 2017, accounting for 24.88% of total exports that year, followed by the United States (20.20%), the Netherlands (9.30%), Poland (5.85%), Thailand (4.12%) and the other countries (35.16%) (FERREIRA; VIEIRA FILHO, 2019).

With the evolution and prominence of Brazilian poultry in the world scenario, the biggest challenge for poultry industries is to maintain the quality of carcasses, since the high number of convictions represents significant losses in the sector (EBLING; BASURCO, 2016).

According to the Management Information System of the Federal Inspection Service (SIGSIF), between 2006 and 2011, the conviction rate in Brazilian refrigerators was 5.99% and the injury accounted for approximately 27.00% of this value (OLIVEIRA *et al*., 2016). Figure 1 illustrates the most common sites of bird bruising during pre-slaughter management.

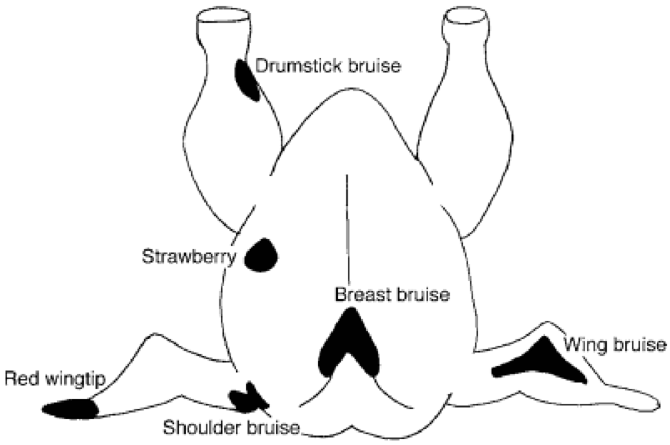

Figure 1 – Common sites of bruising in poultry carcasses
Source: Gregory (1998)

The bruises are caused by acute trauma without fractures and can lead pain and edema (swelling) to high degrees of blood leakage (hematoma). Their occurrence is evidence that there are nonconformities in pre-slaughter processes, such as poultry management, picking, transport, waiting, hanging, stunning and bleeding (LUDTKE *et al*., 2010). In order to reduce bruising, improvement in animal welfare conditions and stress reduction in the execution of pre-slaughter processes must be constantly promoted (DRAIN, 2007; WHITING 2007; SANTANA *et al*., 2008; SILVA *et al*., 2009; VIEIRA *et al*., 2011).

Animal welfare can be defined using the concept of the “Five Animal Freedoms” proposed by the BRAMBELL report (1965) and adopted by the Farm Animal Welfare Council (FAWC), which are: (1) Free from hunger, thirst and bad nutrition; (2) Free from discomfort; (3) Free from pain, injury and disease; (4) Free to express their normal behavior; (5) Free from fear and stress (FAWC, 2009). The “Five Animal Freedoms” provide a set of principles, and the utopian ideals expressed in each freedom represent milestones to be used to assess how far specific practices are meeting the highest welfare standards (MOLENTO, 2005).

In this sense, Ludtke *et al*. (2010) states that pre-slaughter management should meet the following principles: (1) Management methods and facilities that reduce animal stress; (2) Qualified, committed and caring team in the management of birds; (3) Appropriate equipment, properly adjusted to the type and situation to be used and periodically maintained; (4) Effective process of sensitization that induces immediate loss of consciousness and sensitivity, so that there is no recovery of the senses.

The expansion and maintenance of new markets for the Brazilian poultry meat production sector inevitably depend on prioritizing the quality of the raw material. In this context, it is extremely important to reduce losses by identifying anomalies in pre-slaughter management processes, thus maintaining bird welfare and final product quality (VIEIRA, 2008).

One method of assessing animal welfare care is the presence or absence of bruises on the bird's body after the slaughter process. Thus, correctly identifying injuries and their causes provide support for preventive measures to be taken (JAENISCH *et al*. 2016). The most common carcass quality assessment systems are based on visual or aesthetic criteria, such as conformation to a visual pattern, presence of hemorrhages and/or bruises, skin rupture, broken bones and missing parts (MENDES; KOMIYAMA, 2011).

Currently, the task of identifying the root causes of bruising is carried out through empirical investigations in pre-slaughter processes and mainly supported by the experience of the professional analyzing such bruises, so inexperienced professionals may need more time to generate diagnoses and at the same time, they can be mistaken. Thus, there may be increased losses and non-compliance with animal welfare concepts.

This paper aims to demonstrate that Artificial Intelligence (AI) techniques can be applied to partially automate this task to assist professionals in identifying nonconformities in pre-slaughter processes, using the Expert System (ES) approach.

Expert Systems are intelligent computer systems that make extensive use of expertise in problem-solving and decision making at the level of a human expert. This knowledge can be obtained through literature or a person who has experience in a particular area (GIANTARRO; RILEY, 1998). In our research group, different expert systems were developed for the following areas: hydraulic systems maintenance in a concurrent engineering perspective (Silva, 1999), fluid power system design (Silva & Back, 2000), sensor fault modeling (Silva, *et al*., 2012), cogeneration power plants design (Silva, *et al*., 2014), hermetic compressors diagnosis (Pedroso & Silva, 2014), selection of creativity support techniques (Botega and Silva, 2015), among others.

The development of an Expert System takes place in five stages: (1) Feasibility Study: confirming whether the problem can be solved by an ES; (2) Knowledge Acquisition: gathers the information necessary for the development of the system; (3) Knowledge Representation: the information collected is formalized through different techniques; (4) Implementation: translates knowledge into the computational environment; and (5) Verification and Validation: practical evidence that the system provides the adequate output (WATERMAN, 1985).

Previous studies that correlate AI and diagnosis of causes of loss in poultry production have been identified, but none supports the analysis of bruises. Amosa and Faleye (2012) developed an ES using the Prolog programming language to assist in the diagnosis of 11 types of diseases that may occur in birds during the field management step. The knowledge was acquired through literature review and interviews with poultry specialists and implemented in the form of object-oriented representation. Olanloye and Yerokun (2018) also developed an ES implemented by C# language to aid in the diagnosis of diseases in birds during the field management stage, the knowledge base was generated from interviews with veterinarians and poultry breeders as well as described in the form of object-oriented representation. Sanyang and Sapuan (2015) developed an ES to select bio-based polymeric materials suitable for packaging fruits, dried foods and dairy products. The material selection was based on If-Then rules, while a scoring system was formulated to facilitate classification of selected materials and at the end, the ES selected materials that met all restrictions and the results were presented in sequence of suitability depending on their scores.

In this work, the prototype development was considered successful mainly because the expert's knowledge proved to be adequately represented through an incremental model, which means that developers considered the knowledge acquisition, representation, implementation, and validation activities in defined increments as prototype functionality increases. In this way, the prototype through inputs provided to the user, infers rules and solution combinations providing an output with diagnostics that have best practices of pre-slaughter processes that may be non-conforming.

This paper discusses the main concepts related to the diagnosis of poultry bruises in pre-slaughter management processes and their related causes. The second section presents conceptions about the development of the ES and its knowledge acquisition and representation, verification, and validation processes. In the end, a summary of the main conclusions, as well as recommendations for future work and thanks are presented.

2. Materials and methods

This section presents the methodology used in prototype development, as well as the acquisition and representation of knowledge, its implementation, and validation.

2.1. Knowledge acquisition

The acquisition of knowledge occurred through two sources of information: an expert in the poultry processing area and the literature related to the research theme.

The information was obtained in two stages, the first made it possible to identify the main types of bruises that occur in poultry during their pre-slaughter processes, allowing them to be classified into the wing bruise, red wingtip, shoulder bruise, breast bruise, drumstick bruise and in all members (GREGORY, 1998). The second stage consisted of characterizing the bruises, thus it was founded that their coloration indicates the time interval that it occurred: red (up to 2 minutes); dark purplish-red (12 to 36 hours) and yellow and/or green (above 36 hours) (GREGORY, 1998). Colors help to identify if the bruise occurred during the slaughterhouse internal processes. In the third stage, it was identified which pre-slaughter processes are responsible for generating specific types of bruises. However, the data in the literature on the subject are scarce and the expert's assistance was more important, this analysis is qualitative and produces the possibility of a single process being able to generate more than one type of injury, thus, three professionals, with 17, 15 and 4 years of experience working as a team leaders in the slaughter process, were consulted to prioritize for a specific hematoma the processes to be diagnosed. Finally, for each pre-slaughter process, best practices and technical recommendations for its operation were identified in two sources, the first one is the Brazilian Agricultural Research Corporation (EMBRAPA) and the second source is the recommendations for the poultry welfare in pre-slaughter processes developed by the World Society Animal Protection (WSPA).

2.2. Knowledge representation

The knowledge representation for the prototype was developed as an incremental structure using a combination of object-oriented modeling and rules, as shown in (Silva, 1998). The prototype was developed with two object-oriented classes, one for bruise analysis attributes and one for manipulate the information with the end-user (user interface).

2.3. Object-oriented modeling

The object-oriented modeling diagram developed for this prototype is presented in Table 1 defining the class “Bruise Analysis” and its respective attributes composing the slots, which characterize it and are defined as the bruise locations (wing bruise, red wingtip, shoulder bruise, breast bruise, drumstick bruise and in all members) and the colors may represent the time period in which it occurred (red, purple and green and/or yellow). The prototype development applied the incremental life model, with the process being divided into two cycles.

Table 1 - Class attributes for "bruise analysis"

		Class: BRUISE ANALYSIS		
Cycles	**Inputs**	**Questions**	**Attributes**	**Outputs**
1º	Bruise location	Where is the location of the bruise?	a) Wing or shoulder b) Wingtip or breast little specks c) Drumstick d) Breast e) In all parts f) I need held	Diagnosis considers all of possible processes according to their location but without the analysis of their period due to the color of the bruise
2º	Bruise color	What is the color of the bruise?	a) Red b) Purple c) Green and/or yellow d) I need held	Diagnosis now considers the period of the bruise occurrence, increasing its reliability

Source: Authors

In the first implementation cycle, the attributes related to the location of the bruise were established and structured. In this cycle, a single variable was considered, thus, the outputs provided by the ESP emits all the possible processes which can generate a certain bruise without identifying when it occurred. However, with the development of the second increment cycle, the analysis of the second variable provides the ES outputs with more information because it allows the user to identify when and in which process the bruise occurred.

2.4. Rules

Analyzes and decisions to resolve nonconformities in pre-slaughter processes are carried out by domain experts who visually check the hematoma in the poultry. Similarly, the expert system makes use of this logic through rules that are processed by the inference engine. These rules represent the critical thinking developed by the expert in analyzing the possible causes of the bruise.

The diagnosis of poultry bruises in this study involves the analysis of two attributes as mentioned in the Object-Oriented Modeling topic, so the rule development promoted by the inference engine is shown in Figure 2.

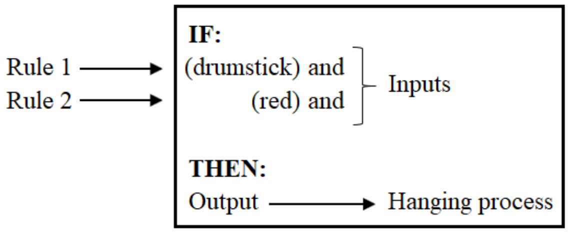

Figure 2 – Example of using the *It – Then* rule

For example, "*If*" the location of the bruise is on the drumstick of the poultry AND "*If*" its color is red, "*Then*" the hanging process caused the nonconformity. The same rule logic was constructed for each heuristic that composes the ES decision making process.

2.5. Implementation

The prototype was implemented through a shell known as CLIPS that provides an environment for the expert systems development, originally developed by the Software Technology Branch (STB), NASA/Lyndon B. Johnson Space Center. The tool is composed of a multiparadigm language where knowledge can be represented in procedural form, based on rules and object-oriented programming (GIARRATANO; RILEY, 1998).

The default CLIPS interaction with the user occur only by text, so the prototype generates an HTML file for each diagnostic generated as an output report.

If the user has any questions regarding the questions provided by the ES, he/she can ask for help. In this way, the program displays an explanatory message to instruct on how to proceed. The prototype initiates the diagnostics collecting the user inputs and through the attributes obtained, activates the rules that satisfy them by generating an HTML output report with the best practices of one or more pre-slaughter processes, as shown in Figure 3.

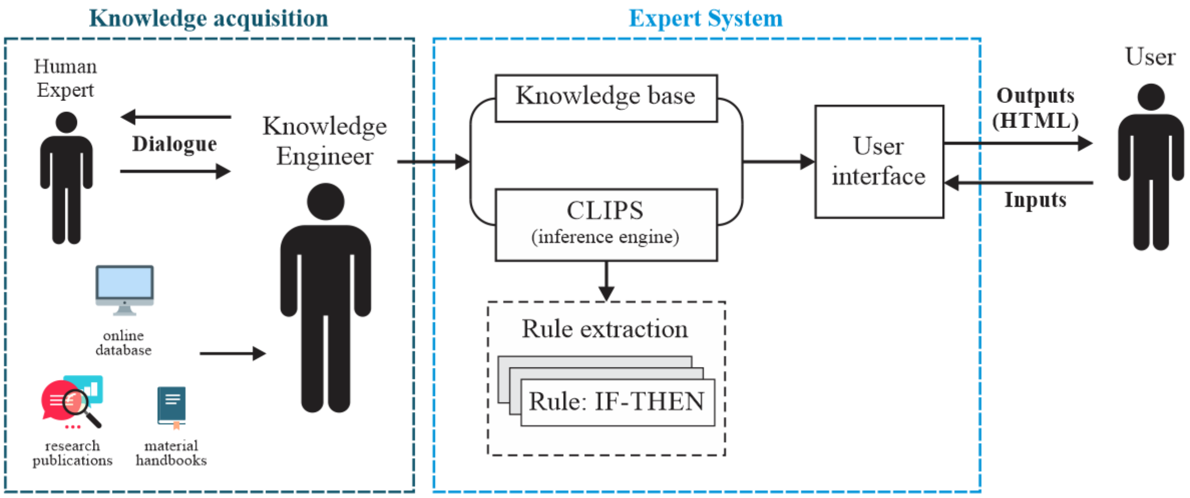

Figure 3 - Knowledge based system development

Figure 3 also illustrates the Knowledge Acquisition process developed by the Knowledge Engineer and represents the kernel that composes the Expert System. This knowledge base can be updated as new knowledge generated about the topic of this study.

2.6. Verification and validation

The questions shown in Table 1 allow a series of response associations, and for each combination, the prototype provides a diagnosis that shows consistency in the outcome.

For the verification step, a truth table shown in Table 2 has been developed in order to check all possible combinations, the system is able to formulate a total of 15 different solutions according to the input combinations provided by the user.

Table 2 - Truth table illustrating all possible response combinations

Question 01: Wing or shoulder Question 02: Red	Hanging and stunning
Question 01: Breast Question 02: Red	
Question 01: Drumstick Question 02: Red	
Question 01: Wing or shoulder Question 02: Purple	Picking, transportation and waiting
Question 01: Wingtip or breast little specks Question 02: Purple	
Question 01: Drumstick Question 02: Purple	
Question 01: Wing or shoulder Question 02: Green and/or yellow	Handling
Question 01: Wingtip or breast little specks Question 02: Green and/or yellow	
Question 01: Breast Question 02: Green and/or yellow	
Question 01: Drumstick Question 02: Green and/or yellow	
Question 01: In all parts Question 02: Green and/or yellow	
Question 01: Wingtip or breast little specks Question 02: Red	Stunning and hanging
Question 01: Breast Question 02: Purple	Transportation and picking
Question 01: In all parts Question 02: Purple	
Question 01: In all parts Question 02: Red	Bleeding

In the validation stage, all possible scenarios were verified and for each combination, a diagnosis supported by the sources cited in the Knowledge Acquisition section was made by the knowledge engineer, the first author with 2 years of experience in this area.

The prototype validation process begins with user inputs and ends with an analysis of the output report containing the diagnostics. These tests are intended to ensure that prototype outputs are aligned with the findings of human experts in the field, so it must be certified that all outputs have been validated.

Two other experts were invited to participate in the prototype validation process. The first has more than 3 years of experience in poultry processing acting as a process manager and the second has 12 years of experience, having worked as an analyst and process specialist comprising the entire poultry processing value chain. Both professionals work in a large slaughterhouse located in Brazil with a daily slaughtering capacity of 330.000 birds and whose production is directed to the international market.

In order to validate the prototype outputs, the specialists simulated the presence of a bruise in the poultry and based on the diagnoses provided, they presented comments and observations regarding the quality of diagnoses. ESP outputs that differed from experts´ responses were discussed and corrected in the software code by the knowledge engineer. After the discussions about all of the 15 different solutions, the experts have confirmed that the diagnostics provided by the ESP are consistent with the practice and also concluded that the ***ESP is useful to help the practitioners to obtain better results when diagnosing bruises in poultry,***

especially when they have no experience in the field. Another utility verified by the experts is the use of the ESP to train new employees and also to store the organizational knowledge and keep it accessible to everyone. An observation made was the need of the ESP to be updated when new information is obtained or when changes are made into the pre-slaughter processes to continually update the software and the need and to include images that may facilitate the understanding of the prototype questions and also guide the user through the adjustment procedures.

To assess the suitability of the prototype user interface, seven non-expert users were invited to test it. After the test, they were asked to answer four questions related to the prototype and for each question a response according to the Likert type scale was required, similar to the approach taken by Silva (1998): (1) Strongly disagree; (2) Partially disagree; (3) Indifferent; (4) I partially agree; (5) I totally agree. The following are the questions with their respective degrees of acceptance:

(I) Is the objective of the prototype understandable?

Answers: 5 users totally agree; 2 users partially agree.

(II) Are the questions provided by the prototype clear?

Answers: 4 users totally agree; 3 users partially agree.

(III) Is it easy to enter input data for analysis?

Answers: 4 users totally agree; 2 users partially agree; 1 user partially disagrees.

(IV) Are the diagnostics contained in the prototype outputs clear?

Answers: 1 user totally agrees; 4 users partially agree; 2 users were indifferent.

The first question showed that non-expert users satisfactorily understood the purpose of the prototype and therefore all showed positive responses. Because the questions posed by the prototype were simple, all users participating in the survey could clearly understand what was being asked in the second question. The third question presented one negative feedback, so, although the authors developed a manual for installation and execution of the prototype, the user reported that he had difficulties in executing it. Finally, the fourth question presented two indifferent opinions and, in this case, these two users suggested the insertion of images that may facilitate the understanding of the diagnosis.

3. Results and discussion

In order to demonstrate the results obtained with the prototype, two diagnostic examples are presented. The examples show data entry process, the information exchange between the prototype and the user, as well as the diagnosis presented at the end of the process.

Through the questions and alternatives contained in Table 1, the user enters with information into the ES about the location and the color of the bruise.

Figure 4a illustrates the first example where a drumstick bruise with a red color is analyzed. As an output, the prototype generates a diagnostic indicating which processes are more likely to be responsible for the bruise, in this case, those that should be prioritized in the investigation are hanging and stunning. The diagnosis also contains good practices of the respective processes in order to prevent the recurrence of nonconformities.

The second example shows a bruise that has occurred on the breast of the poultry with a green and/or yellow aspect. The output reported for this example is shown in Figure 4b and the hanging process is indicated by bruise occurrence.

ES diagnosis for input data

The red color is an indicator of recent occurrence (a few minutes) of the bruise and has already occurred in the production line.

Please evaluate the execution of the processes listed in the following order:

HANGING:
- Poor lighting: low light levels have a calming effect and reduce the beat frequency of the wings. It is recommended to use blue light evenly distributed throughout the process;
- Parapet: the parapet should be placed before hanging and must maintain continuous contact with all birds until the entry into the stunning bowl. The base of the support should be below or at the height of the bird's head to limit vision and thereby reduce distractions that stimulate bird activity. The material used must be rigid, smooth, fixed and easy to clean;
- The time between hanging and stunning processes: 12 to 60 seconds is recommended to avoid the discomfort generated by the inverted disposition;
- Hooks: hooks should be of appropriate size and positioned to allow easy access to the legs of the birds. They must be wet before the birds are hung to facilitate the passing of the electric current in the process of stunning and must be hung by both legs;
- Operator practice: Operator skill can reduce wing flap when birds are hung. If handled gently after hanging, keeping the hand on the bird's body to restrain it for 1 or 2 seconds, the birds calm down and the flutter of wings slows;
- Disturbances around the line: birds may consider humans to be a predator, movement of people in the hanging area may lead to increased wing flap. While birds are alive, avoid traffic or only if necessary.

STUNNING:
- Electrodes: They must extend completely over the entire width and length of the bowl to distribute the electric current evenly. The head of the bird must be no more than 5 cm from the electrode distance;
- Electric current: It must be ensured that 120 mA is applied per bird to the stunning current for at least 3 to 4 seconds of application. For high frequency electrical stunning, it is recommended above 400 Hz and below 800 Hz;
- Pre-shock: occurs when there is the contact of the bird with electrified water before being numb in the vat, so it is necessary to attend to:

(1) Stunting vats: they must not overflow, they must be electrically insulated and an electrically isolated sloping ramp should be adjusted so that they retain the birds' heads and necks so that when they start the vats are immediately immersed before any other part of the birds' body touches the electrified water and does not act as an obstacle;
(2) Low line speed: may cause wings to touch water before head immersion.

- Water renewal should occur in all process sanitization processes as described in the operating standard.

(a)

ES diagnosis for input data

The green color is an indicator of the occurrence of hours (over 36 hours) of the bruise and probably did not occur on the production line.

Please evaluate the execution of the listed process:

HANDLING:
In a production system, chickens should be provided with protection and comfort, freedom of movement with sufficient space for recreation, water, quality food and free access to feeders and drinkers. The procedures adopted should favor the welfare and performance of birds.

- Chicks should be distributed homogeneously to the heat source, with free access to feeders and drinkers. Trays should be stocked with small amounts of feed several times a day to ensure comfortable consumption. From the 4th day onwards, replace 1/3 of the initial equipment (tray type feeders and pressure drinkers) with definitive equipment, gradually following until the total replacement around the 6th day;
- Adjustment of equipment: from the second week onwards, the base of the drinking troughs should be at chest level, the base of the troughs should be at chest level and the base of the pendulum troughs at the back. Nipple type must be slightly above the head, depending on the age of the chickens;
- From day 8 the total area of the aviary should be gradually increased so that on the 28th day the entire aviary is occupied, with definitive feeders and drinking fountains evenly distributed;
- Density: should be kept between 10 and 18 birds / m², with production of 20 to 35 kg live weight / m²;
- Lighting: The number of lighting hours corresponding to the age of the chicks must be provided by lamps with energy from 2 to 3 watts / m². A minimum of 4 hours of darkness must be ensured for bird rest;
- Ventilation system: should only be activated when the ambient temperature exceeds 26ºC. As for the nebulization system, it should be turned off when the relative humidity exceeds 80%;
- Aviary litter: it avoids direct contact of the bird with the floor, absorbs moisture and contributes to reducing temperature fluctuations in the house. For this, the bedding work must be constant and throughout the rearing period, in order to keep it fluffy and prevent it from becoming wet by providing the formation of slabs or cascades. Thus, the litter must have a known origin, not come from wood industries that do chemical preservation of wood, must be free of fungi, be dry and have a good absorption capacity.

(b)

Figure 4 - Diagnosis presented by prototype for (a) first example and (b) second example

With the above examples it is possible to verify that the prototype presents the results for the bruise problems that occurred at the beginning and the end of the pre-slaughtering process and contributes to guide inexperienced professionals, thus the use of prototype can improve quality of the diagnosis and reduce time and cost.

As discussed in the Knowledge Acquisition section, nonconformities in a single pre-slaughter process can cause bruises on different parts of the poultry body. Due to the complexity of the poultry processing value chain, the diagnostics provided by the prototype establish a direction to check nonconformities based on the experience of professionals in this area and do not represent an absolute truth. Thus, the user must analyze the entire process and follow the procedures indicated by the diagnosis and if no nonconformities were found, the user should perform an analysis on other processes that composes the pre-slaughter value chain.

4. Conclusion

The main conclusions and contributions of the developed prototype are shown below:

- The ES developed complies with the continuous search of the animal welfare, assisting in the quality of poultry hematoma diagnosis and reducing analysis time, as it directs the user to specific processes and provides a description of the best practices to ensure compliance;

- The prototype stores information present in the literature regarding the subject and also allows knowledge sharing of among more experienced specialists in the diagnosis of poultry injuries and professionals with less experience;

- The system can be used as a tool to train new professionals to diagnose poultry bruises and contribute to meeting animal welfare requirements;

- The prototype must be continually incremented as new information about pre-slaughter processes is identified so that it will maintain a better perform to its function;

- Future works consider: implement figures in the inputs and outputs of the ES that facilitate understanding of the user during the diagnostic consultation. The development of quantitative criteria for the prioritization of pre-slaughter processes to be diagnosed according to the bruise analyzed for a better performance.

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