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GRT suínos: risk management system for thermal comfort in pigs

Fabiano Gregolin de Campos Bueno

Thesis presented to obtain the degree of Doctor in Science. Area: Agricultural Systems Engineering

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Bachelor of Administration

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1. Riscos térmicos 2. Riscos na suinocultura 3. Gestão de riscos na suinocultura 4. Aplicativo de gestão de riscos 5. Conforto térmico de suínos I. Título

Dedication

I dedicate this work to all those who understood my absence and supported me during this period, recognizing the importance of this work for my academic and professional life. Your support was fundamental for me to fully devote myself to this project and achieve this important objective.

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CONTENTS

RESUMO

GRT suínos: sistema de gerenciamento de risco no conforto térmico de suínos

A produção de suínos está sujeita a diversos fatores limitantes da eficiência produtiva, destacando-se entre eles o ambiente climático. A busca de alternativas para minimizar o desafio térmico dos animais é imprescindível, o que torna a atividade gerencial dos produtores de suínos altamente complexa. Nesse sentido, uma área que pode oferecer suporte expressivo na tomada de decisões dos produtores de suínos é a gestão de riscos. Na suinocultura, como em toda atividade agropecuária, os riscos são inerentes e envolvem todas as etapas do processo produtivo. As pesquisas direcionadas à gestão de riscos são abundantes, mas dirigidas a temas específicos, no entanto, pesquisas voltadas à gestão de riscos no conforto térmico de suínos, com uma abordagem integrativa, é um campo inexplorado. O propósito deste estudo foi desenvolver o aplicativo Gestão de Riscos Térmicos em Suínos – GRT Suínos, para tanto, o estudo foi dividido em 3 etapas. A primeira foi a realização de uma revisão sistematizada, com o objetivo de encontrar o estado da arte da temática gestão de riscos em suínos. A segunda consistiu em criar uma ferramenta que oriente os produtores na identificação dos riscos no conforto térmico dos suínos, adotando-se uma abordagem construtivista com a criação de um novo modelo, baseado numa extensa revisão bibliográfica e em dados empíricos, tendo como resultado um mapa de riscos no conforto térmico de suínos. A terceira etapa teve por objetivo criar, desenvolver e validar o aplicativo GRT Suínos, desenvolvido no sistema operacional Android, tendo sua construção baseada no método Scrum. Os resultados demonstraram que o GRT Suínos é um recurso inovador, que permite ao usuário gerenciar riscos térmicos em suínos, tendo sua aceitabilidade comprovada pelo alto índice de satisfação dos usuários e boa usabilidade. O GRT Suínos é uma inovação importante na inserção da Gestão de riscos na área da suinocultura, abrindo um grande campo para pesquisas futuras.

Palavras-chave: Riscos térmicos, Riscos na suinocultura, Gestão de riscos na suinocultura, Aplicativo de gestão de riscos, Conforto térmico de suínos

ABSTRACT

GRT suínos: risk management system for thermal comfort in pigs

Pig production is subject to various factors that limit production efficiency, with climatic environment being among the most significant. Seeking alternatives to minimize the animals' thermal challenge is essential, making swine producers' managerial activity highly complex. In this sense, an area that can offer significant support in swine producers' decision-making is risk management. In pig farming, as in all agricultural activities, risks are inherent and involve all stages of the production process. Research focused on risk management is abundant but directed towards specific themes. However, research aimed at risk management in pig thermal comfort, with an integrative approach, is an unexplored field. The purpose of this study was to develop the Thermal Risk Management in pigs – GRT Suínos. Therefore, the study was divided into three stages. The first was a systematic review to find the state of the art in risk management in pigs. The second stage consisted of creating a tool that guides producers in identifying risks in pig thermal comfort, adopting a constructivist approach with the creation of a new model based on an extensive literature review and empirical data, resulting in a map of risks in pig thermal comfort. The third stage aimed to create, develop, and validate the GRT Suínos, developed on the Android operating system, based on the Scrum method. The results showed that GRT Suínos is an innovative resource that allows users to manage thermal risks in pigs, with its acceptability proven by the high satisfaction rate of users and good usability. GRT Suínos is an important innovation in introducing risk management in the swine farming sector, opening up a vast field for future research.

Keywords: Thermal risks, Risks in pig farming, Risk management in pig farming, Risk management app, Pig thermal comfort

1. INTRODUCTION

In recent decades, there has been an increase in demand for the consumption of animal protein, which has been boosted by the growth of per capita income and population size. (Godfray et al. 2018; Whitnall and Pitts 2019). According to estimates, global animal production is expected to double by the year 2050 (Gerber et al., 2010; Ilea, 2009). In line with this trend, levels of pork consumption have substantially increased in recent years. (Lassaletta et al. 2014; Szűcs and Vida 2017). This increase, together with the globalization of the economy and advancements in trade, capital flows, and technology, emerges as a driving force for the development of the swine production sector. (Robinson et al., 2011; Szymańska, 2017).

This dynamic has motivated transformations in production systems in several countries, with the transition from extensive, small-scale, subsistence, and mixed production systems to intensive, large-scale, more geographically concentrated, specialized, and market-oriented productions (Robinson et al., 2011). Intensive pig production systems are characterized by the presence of robust infrastructure, attention to animal health and nutrition, use of advanced technology, specialized technical team, utilization of selected breeds, and other attributes that allow for a significant increase in productivity. (Thanapongtharm et al., 2016).

The high performance of pig production generates a series of consequences, such as the emergence of environmental issues that permeate the entire production and supply chain (Sage, 2011; Winkler et al., 2016), land use (Doelman et al., 2018), waste management (Willems et al., 2016), farm income and the livelihoods of farmers, animal health and welfare, product safety and quality, working conditions (Dolman et al., 2012; Schodl et al., 2017), biosecurity (Alarcón et al., 2021), characterizing intensive pig production as a complex and comprehensive activity (Davies, 2011; Okello et al., 2015).

This inherent complexity in pig production demands equally complex management actions. In this sense, one area that can offer significant support to producers is risk management. By measuring and managing risks in a systematic and consistent way, precise and relevant information is obtained that allows for an analysis of the risk-return relationship. Thus, the company strengthens its ability to effectively execute its strategic plan (Nocco & Stulz, 2006).

In pig farming, as in other agricultural activities, risks are inherent and present in all stages of the production process. Research conducted in this area is numerous, but is directed to specific fields, without a specific methodological approach from the risk management area.

Such research has focused only on issues that can affect breeding outcomes, such as animal stress (Mutua et al., 2020), antibiotic use (Tiseo et al., 2020), waste management (Tigini et al., 2016), profitability (Pereira & de Melo, 2019), alternative systems (Delsart et al., 2020), biosecurity (Alarcón et al., 2021), animal welfare (Marchant-Forde, 1981), supply chain (Wu et al., 2017), feeding (Kil et al., 2013), transportation (Zurbrigg et al., 2017), producer decision-making (Franken et al., 2017), among other segments.

These factors are limiting the productive efficiency, among them, the climate environment stands out (Rauw et al. 2020). The recognition of the effects of ambient temperature on pig production has boosted research in search of alternatives that can minimize the thermal challenges faced by the animals (Renaudeau et al. 2012). The productive efficiency and final meat quality are closely linked to the physiological and metabolic responses associated with thermal stress (Gonzalez-Rivas et al. 2020). Thermal stress represents a threat to the animal's homeostasis, as it will require additional energy expenditure to maintain body temperature, reducing feed conversion results. This increase in energy requirement raises production costs, reduces efficiency and profitability (Collier et al. 2017). In this sense, it becomes essential to direct efforts towards the development of systems that can assist pig producers in the process of management and decision-making.

The research that resulted in this thesis aimed at the development of the GRT Suínos app, a risk management system for thermal comfort in pigs. To achieve this general objective, it was necessary to reach the specific objectives: (i) conducting a thorough literature review to gather available information on risks in pig farming, identifying how the topic has been addressed in recent research through a systematic review covering the period from 2015 to 2021. (ii) creating a tool to guide producers in identifying risks related to thermal comfort of pigs, resulting in a map of risks in the thermal comfort of pigs, an innovative tool that guides producers in identifying factors that may represent risks to animal thermal comfort. (iii) creating, developing, and validating the GRT Suínos app for thermal comfort management in pigs, with a holistic approach structured around the map of risks in the thermal comfort of pigs.

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2. RISK MANAGEMENT IN PIG FARMING: A REALITY OR CONJECTURE? A SYSTEMATIC REVIEW

Abstract

Context: The complexity in swine production demands equally complex management actions. In this sense, risk management is an area that has been little explored and that may offer significant contributions to pork producers in their decision-making processes.

Aims: This study aimed to collect the available information on risks in pig farming and identify how the topic has been approached in recent studies.

Methods: A systematic review was carried out based on searches in the Web of Science, Scopus and Science Direct databases, in the period ranging from 2015 to 2021. The searches resulted in 2,178 documents on the theme risks in pig farming, which were then classified into 13 categories to represent the general objective of each study and into 177 subcategories representing the specific objective of each work. The data, separated into categories and subcategories, was not classified by any exclusionary criteria. On the contrary, they represent all the information found in the studied documents.

Key results: The results show that, although the number of studies on risks in pig farming is growing, the studies are contained in specific fields only. It was also possible to observe that although the studies focused on problems that may affect pig raising, they were not approached in a holistic manner using risk management methodologies that would allow identifying, measuring and managing risks in a consistent and systematic way. Thus the studies cannot be characterized as having a risk management approach.

Conclusion: The studies on risks in pig farming focus on specific areas instead of using an integrated approach. It found that risks in pig farming are a growing concern, but a holistic approach to the subject is still unexplored and could be quite fruitful, as it would make it possible to identify, measure and manage risks in a more consistent and systematic way.

Implications: Producers, veterinarians, managers and researchers can use the results of this study (i) to develop identification systems, and (ii) in quantitative and qualitative analyses, planning, implementation of responses and monitoring of risks in pig farming.

Keywords: Risks; Risk management; Risks in pig farming; Pig farming.

2.1. Introduction

Animal protein consumption has been increasing in recent decades, driven by the rising average individual income and population growth (Godfray *et al.* 2018; Whitnall and Pitts 2019). It is estimated that by 2050, global animal production will have doubled (Ilea 2009; Gerber *et al.* 2010). Pork consumption has substantially increased in recent years (Lasaletta *et al*. 2014; Szűcs and Vida 2017). This increase, together with the globalization of the economy, trade development, capital flows and technology are the drivers for the development of the swine production sector (Robinson *et al.* 2011; Szymańska 2017). Such dynamics has led to changes in production systems in some countries, which went from extensive, small-scale, subsistence and mixed production systems to intensive, large-scale, more geographically concentrated, specialized and commercially-oriented production systems

(Robinson *et al.* 2011). Intensive swine production systems are characterized by robust infrastructure, nutrition and health care, technology, specialized personnel and selected breeds, attributes that allow an increased productivity with high-yield animals (Thanapongtharm *et al.* 2016).

Such swine production performance leads to consequences involving environmental issues along the production and supply chain (Sage 2011; Winkler *et al.* 2016); land use (Doelman *et al*. 2018); waste management (Willems *et al.* 2016); farm income and farmers' livelihoods, animal health and welfare, product safety and quality, working conditions (Dolman *et al.* 2012; Schodl *et al.* 2017); and biosecurity (Alarcón *et al.* 2021), all of which result in intensive swine production being characterized as a complex and comprehensive activity (Davies 2011; Okello *et al.* 2015).

The complexity in swine production demands management actions that are equally complex. In this sense, an area that may significantly help pork producers with their decision-making is risk management. By measuring and managing risks consistently and systematically, and consequently obtaining accurate and highly relevant information that allows the analysis of the risk-return relationship, companies may strengthen their ability to carry out strategic plans (Nocco and Stulz 2006). *Enterprise Risk Management* (ERM) can create value at the macro level, allowing senior management to quantify and manage the risk-return tradeoff, in order to support the decisions necessary to implement the strategy, and at the micro level, transforming the company's culture (Nocco and Stulz 2006).

Risk is the possibility that an event will occur and adversely affect the planned goals (COSO 2018). Regardless of their type or size, organizations are influenced by external and internal factors that make the achievement of their objectives uncertain; the effect such uncertainties have on the objectives is understood as risk (Hutchins 2018). Risk is the possibility of something not going right. However, its current concept involves the quantification and qualification of uncertainty, both in terms of losses and gains in relation to the course of planned events, whether by individuals or by organizations (La Rock 2007). Risk can be defined as the combination of the probability of an event happening and its consequences (FERMA 2002).

As in all other farming activities, risks are inherent to pig farming and involve all stages of the production process. Research in this area is abundant, but directed at specific fields and carried out without the use of specific methodologies in the area of risk management, focusing only on problems that may affect breeding, such as: animal stress (Mutua *et al.* 2020), antibiotic use (Tiseo *et al.* 2020), excrement (Tigini *et al.* 2016), profitability (Pereira and de Melo 2019), alternative systems (Delsart *et al.* 2020), biosecurity (Alarcón *et al.* 2021), animal welfare (Marchant-Forde 1981), the supply chain (Wu *et al.* 2017), feed (Kil et al. 2013), transport (Zurbrigg *et al.* 2017), decision-making by producers (Franken *et al.* 2017), among others. Research focused on risk management in pig farming with an integrative approach (that would allow measuring and managing risks in a more consistent and systematic way and, as a result, help the producer in decision-making) would be fruitful, but is still unexplored, so much so that no publication dealing with risk management in pig farming, in an integrative and methodological way, was found in the search. In order to prove this gap, the systematic review conducted in the present study gathered the available information on risks in pig farming and created a library containing the findings obtained in the systematized searches and their respective analyses.

2.2. Conclusion

This research study identified that studies on risks in pig farming focus on specific areas instead of using an integrated approach. Publications are plentiful, but concentrated on issues that may affect the results in pig raising, rather than using an approach with specific methodologies in the area of risk management. It found that risks in pig farming are a growing concern, but a holistic approach to the subject is still unexplored and could be quite fruitful, as it would make it possible to identify, measure and manage risks in a more consistent and systematic way. Producers, veterinarians, managers and researchers can use the results of this study (i) to develop identification systems, and (ii) in quantitative and qualitative analyses, planning, implementation of responses and monitoring of risks in pig farming. The results of this study contribute to advancements in the area, demonstrating that risk management in pig farming is still very incipient and is a vast field to be explored in the pursuit of increased productive efficiency and animal welfare.

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3. RISKS IN SWINE THERMAL COMFORT: A PROPOSED RISK MAP

Abstract

Context: Pig production is subject to various factors that limit production efficiency, with climate being a key factor among them. The search for alternatives to minimize the thermal challenge for animals is essential, making the management of pig producers highly complex. In this sense, an area that can offer significant support in decision-making for pig producers is risk management. In pig farming, as in all agricultural activities, risks are inherent and involve all stages of the production process. Research on risk management is abundant, but it is directed towards specific topics. However, research focused on risk management in pig farming with an integrative approach is a field that has been little explored.

Aims: The purpose of this research was to create a tool that guides producers in identifying risks related to the thermal comfort of pigs, adopting a constructivist approach with the creation of a new model based on an extensive literature review and empirical data.

Methods: After the development of a pig farming risk map based on an in-depth literature review, brainstorming meetings were held to identify risks that negatively affect pig thermal comfort. The risks were analyzed and grouped by similarity, and the risk map was tested and validated with a group of professionals from the pig production system in Brazil. The enhanced tool was subsequently tested on a farm with over 50,000 animals.

Key results: The result is the Risk Map in Swine Thermal Comfort, an important tool that will guide producers in identifying factors that may represent risks in the thermal comfort of animals.

Conclusion: This research has unveiled an innovative proposal for risk identification by presenting the Risk Map in Swine Thermal Comfort, an important tool that will guide producers in identifying factors that may pose risks to animal thermal comfort.

Implications: The identification of risks represents an essential step in the creation and development of risk management processes with a holistic approach, and having a tool that guides this identification process is a substantial contribution to producers and to the advancement of the field.

Keywords: Risks; Risk management; Thermal comfort; Pigs; Risk map; Management tool; Innovative tool; Pig farm management.

3.1. Introduction

The consumption of animal protein has been increasing in recent decades, boosted by the increase in individual average income and population growth (Godfray *et al.* 2018; Whitnall and Pitts 2019). Global meat production is expected to reach 361 million tons in 2022, boosted by significant growth in meat production in China, as well as relevant increases in Brazil, Australia, and Vietnam. The largest volume gain is expected to come from pork, with estimates reaching 125.6 million tons in 2022, surpassing the 109.8 million tons of 2020 and the 122.5 million tons of 2021 (FAO 2022). Following this growth trend, pig production must adopt various systems with different levels of technical development, ranging from family or backyard farming to intensive production systems. (Lassaletta *et al.* 2019)

Pig production is subject to various factors that limit production efficiency, with climate being a key factor among them (Rauw *et al.* 2020). The recognition of the effects of environmental temperature on pig production has boosted research in the search for alternatives to minimize the thermal challenge for animals (Renaudeau *et al.* 2012). Productive efficiency and final meat quality are closely linked to the physiological and metabolic responses associated with heat stress (Gonzalez-Rivas *et al.* 2020). Heat stress represents a threat to the animal's homeostasis, as it will have additional energy expenditures to maintain body temperature, decreasing feed conversion results. This increase in energy requirements raises production costs, reduces efficiency, and profitability (Collier *et al.* 2017).

In this perspective, the management activity of pig producers is highly complex. Activities such as management, internal and external controls, monitoring, purchasing, sales, personnel management, asset management, health control, financial control, and various other actions and decisions are assigned to producers who are not always prepared for such tasks (Oosthuizen and Janovsky 1981).

With all this complexity, an area that can offer significant support in the decision-making process of pig producers is risk management. By measuring and managing risks in a consistent and systematic way that provides accurate and relevant information, enhancing the risk-return analysis, it is possible to strengthen the ability to achieve production objectives. In pig farming, as in all agricultural activities, risks are inherent and involve all stages of the production process. Research in this area is abundant but directed to specific fields. However, research focused on risk management in pig farming with an integrative approach is an area that is still poorly explored (Gregolin and Silva Miranda 2022).

Therefore, it is essential to direct efforts towards the development of tools that assist producers in the management and decision-making process. This research aimed to develop an innovative tool for identifying risks, the Risk Map in Swine Thermal Comfort.

3.2. Final Considerations

This research has unveiled an innovative proposal for risk identification by presenting the Risk Map in Swine Thermal Comfort, an important tool that will guide producers in identifying factors that may pose risks to animal thermal comfort. Identifying risks is an essential step in creating and developing a holistic risk management process, and having a tool that guides this identification process is a substantial contribution to both producers and the advancement of the field.

Future studies can expand the number of risks on the map, further refining the tool and expanding its applicability. Nevertheless, this new tool, and others that may be developed, need to be tested with enough producers, enabling not only improvements to the tool but also the emergence of other tools that meet the specific characteristics of different types of farming.

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4. DEVELOPMENT AND VALIDATION OF A MOBILE APPLICATION FOR THERMAL RISK MANAGEMENT IN PIGS – GRT SUÍNOS

Abstract

The animal production industry is undergoing an exponential technological transformation through the incorporation of new software and hardware. These technologies aim to support and improve decision-making on agricultural properties, increase production efficiency, minimize economic risks, and promote new breeding systems. Among the various challenges in pig farming, ensuring thermal comfort is often one of the most critical. Technological solutions that assist producers in making decisions regarding thermal comfort risks for pigs have not been identified during research. This article proposes an innovative solution for managing risks related to animal thermal comfort, the GRT Suínos app. The objective was to create, develop, and validate the app, developed on the Android operating system, based on the Scrum method. The main innovation of the app is its ability to guide the producer in identifying, analyzing, and evaluating thermal comfort risks for pigs, allowing the generation of a management report with proposals for possible treatments for these risks at the end of the process. The study's findings resulted in a high level of user satisfaction and good usability, confirming the app's acceptability.

4.1. Introduction

The animal production industry is undergoing an exponential technological transformation through the incorporation of new software and hardware. The main objective of these technologies is to support and improve decision-making on agricultural properties, increasing production efficiency, minimizing economic risks, and promoting new breeding systems. (Benjamin & Yik, 2019; Borges Oliveira et al., 2021; Mahfuz et al., 2022)

Among the various challenges in swine farming, ensuring thermal comfort is often one of the most critical. Thermal stress is caused by the exposure of animals to environments that hinder their thermal regulation, which can negatively affect various management stages, from physical and immune development to meat and other product production. When animals are subjected to adverse thermal conditions, they exhibit reduced food and water consumption, which can affect growth and feed efficiency. In addition, thermal stress can weaken the immune system, increasing the risk of diseases, and consequently, affecting the quality of meat, including flavor, texture, and appearance. (Hennig-Pauka & von Altrock, 2022; Lammers et al., 2022)

Although it is widely recognized that heat stress can have significantly negative effects on the management and production of pigs, data collection and management on this subject is still insufficient. The lack of accurate and consistent information makes decision-making difficult. Moreover, the lack of data also limits the ability to assess the real impact of heat stress on animal welfare conditions, production efficiency, and product quality. (Guevara et al., 2022; Mayorga et al., 2019; Piñeiro et al., 2019)

The migration of data management to smartphones and tablets has been a growing trend in recent years, mainly due to the popularization of these devices. Furthermore, the evolution of mobile technology and the availability of advanced applications have made data management on mobile devices even simpler and more efficient. This shift has enabled greater flexibility and agility in data management, facilitating access to information and allowing for faster and more accurate decision-making. (Neethirajan & Kemp, 2021; Tam et al., 2020)

The Android Operating System, released by Google in 2008, is currently the market leader in mobile devices. One of its main advantages is the open-source license, allowing the creation of high-tech applications at reasonable costs. Additionally, the widespread availability of Android devices and its ease of use make it attractive to many users. (Almomani & Khayer, 2020).

The aim of this study was to create, develop, and validate the mobile application for thermal risk management in pigs – GRT Suínos – produced in the Android operating system, for the management of thermal comfort in swine, based on the risk map proposal by Gregolin; Silva Miranda.

4.2. Final Considerations

GRT Suínos is an innovative resource that allows users to manage thermal risks in pigs. The study findings resulted in a high level of user satisfaction and good usability, confirming its acceptability. Due to its innovative nature, further research is necessary to contribute to the maturity of the application, as well as efforts to expand specific studies on risk management in pig farming, an area that has shown to have enormous potential for exploration.

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