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Welcome message from Editor-in-Chief

Dear authors, reviewers, and readers

It is our great honor to present the second issue of the second volume of the Journal of Science and Agricultural Technology (JSAT), the official journal of the Faculty of Science and Agricultural Technology, Rajamangala University of Technology Lanna (RMUTL), Thailand. In this issue, the contribution includes five articles from Indonesia, Mexico, and Thailand. The JSAT has been published in Thai Journal Online (ThaiJO), indexed in Google Scholar, and Digital Object Identifier (DOI) under the National Research Council of Thailand. The journal will keep on publishing high-quality articles under an intense peer-review process with strongly supports from various educational institutions domestically and abroad.

As an Editor-in-Chief, I promise to move forwards to gain international recognition preparing for a higher index ranking. Besides, I strongly encourage researchers around the grobe to submit manuscripts to share knowledge and promote the growing field of science and agricultural technology. I am so grateful for those supports from our submitting authors, reviewers, and staffs. Without you, the success of the current issue would not be possible.

Kind regards,

Assoc. Prof. Dr. Suntorn Wittayakun
Editor-in-Chief Journal of Science and Agricultural Technology
Dean of the Faculty of Science and Agricultural Technology
Rajamangala University of Technology Lanna, Thailand.

ABOUT THE JOURNAL

Journal of Science and Agricultural Technology (JSAT) publishes original research contributions covering science and agricultural technology such as:

• Natural and applied sciences: biology, chemistry, computer science, physics, material science and related fields. Papers in mathematics and statistics are also welcomed, but should be of an applied nature rather than purely theoretical.

• Agricultural technology: plant science, animal science, aquatic science, food science, biotechnology, applied microbiology, agricultural machinery, agricultural engineering and related fields.

Furthermore, the JSAT journal aims to span the whole range of researches from local to global application.

The JSAT is published two issues a year.
 Issue 1: January - June
 Issue 2: July - December

Submissions are welcomed from international and Thai institutions. All submissions must be original research not previously published or simultaneously submitted for publication or submitted to other journals. Manuscripts are peer reviewed using the double-blinded review system by at least 2 reviewers before acceptance. There is no publication or processing fee.

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Review Article
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Coffivino process: A new era of coffee fermentation

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ABSTRACT

Developing the quality of fermentation is a crucial step in developing regular coffee to specialty coffee. Therefore, the Arabica Research Team, Rajamangala University of Technology Lanna, Thailand, has invented a new fermentation technique called the "Coffivino process." The aim is to create specialty coffee with a consistent level of quality in every season on an industrial level. This technique is inspired by wine fermentation technology, which combines the Semi-carbonic maceration process with the Yeast process. The new process matches the type and quantity of nutrients with the desired coffee cherry quality. Analyzing and controlling the quality of the entire fermentation process shows that the Coffivino process can create coffee with unique attributes, a wider variety of flavors, and higher intensity than the traditional process. This new technique would be the perfect solution for the fermentation of unhealthy quality coffee cherries on an industrial level and improve them to the sensory quality of specialty coffee.

Keywords: Coffivino, coffee, fermentation, semi-carbonic maceration, yeast, Arabica

INTRODUCTION

The unique characteristics of each type of coffee depend on its origin (climate, latitude, altitude, and farm and process management (Alves et al., 2011; Joet et al., 2010). Within the world of specialty coffee, coffee cultivated in suitable environments is born to be remarkable. In other words, they can effortlessly display their unique features, deserving of the name "specialty coffee." However, what about coffee, which was not born to be unique? Not all coffee was cultivated from the ideal environments; these coffees require extra efforts to elevate their sensory property to "Specialty coffee."

Elevating regular coffee to specialty coffee is a challenging topic for any scientists involved in the industry of coffee production. Many research papers agree that in addition to coffee variety, and coffee origin, the development of the coffee fermentation process also plays a major role in developing coffee quality (Ribeiro et al., 2017).

As time passes, consumers are increasingly aware of coffee quality and the property of good coffee. Hence, the standard of coffee is getting higher and higher (Ashihara and Crozier, 2001; Upadhyay and Mohan, 2013). As such, process developers in the 21st Century have turned their interests to control coffee quality through technologies and innovations, hoping to produce a larger quantity of coffee at a similar rate in every harvest season.

At present, wine fermentation technologies are gaining popularity in coffee fermentation processes, including the pre-treatment of coffee cherries by using the Semi-carbonic maceration process (Promsri, 2018; Junior et al., 2020; Jitjaroen et al., 2021) and the Yeast process (Evangelista et al., 2014; Martinez et al., 2017; Jitjaroen et al., 2021). However, worldwide, there are currently only a small number of researches to support this. The Arabica Research Team, Rajamangala University of Technology Lanna, Thailand, is the first to study this new technique using scientific research methods. The purpose of this research is to improve the quality of Thai coffee, with "Specialty coffee go green by using innovative process" at its core. This leads to the improvement of coffee, with an origin of fewer than 1,000 meters above sea level, into specialty coffee (Jitjaroen et al., 2021).

Arabica Research Team has started developing the quality of Arabica coffee by using this new process since 2018 (Jitjaroen et al., 2018; 2021). The research was a success, and the team was able to train farmers, processors, and the general public during the 2021 harvest. Arabica Research Team has combined knowledge and experience to develop this new coffee processing technique by using "Full wine fermentation style" This new coffee processing technique has been named "Coffivino process (CV)."

COFFIVINO PROCESS

Principle of Coffivino Process

Coffivino process (Coffee-vi-no) is a simple combination of the words "Coffee" and "Vino." The word "coffee" means coffee, and the word "vino" (vi-no) is an Italian and Spanish word for "wine" in honor of the wine fermentation process, which has been integrated with the knowledge of coffee making. This new process has been designed to meet the requirement of "creating floral fragrances, increase fruity acidity, heavier body, a balance in taste, and a long aftertaste."

Knowing and understanding the quality of coffee is the key to the Coffivino process, especially understanding the quality of intact mucilage, which varies depending on the coffee variety and the maturation stage of coffee cherries (Meenakshi and Jagan, 2007). The chemical characteristics of mucilage can be easily determined; hence, it is used as the primary parameter in designing a fermentation profile in the Coffivino process.

The quality of intact mucilage will affect important fermentation precursors such as sugar, nutrients, and necessary minerals. Once the quality of the coffee cherry has been determined, the coffee cherries will be treated using the Semi-carbonic maceration process by controlling temperature, and carbon dioxide within the closed fermentation tank, creating an anaerobic fermentation. This will result in the coffee cherries changing from oxygen-based respiration to an intracellular fermentation, creating many important substances and a small amount of ethanol (Tesniere and Flanzy, 2011; Liu et al., 2014; Aiemchai 2020; Soykaew 2020), which are needed to create desirable flavors during the following fermentation process. At the same time, coffee mucilage will be degraded into monosaccharides (Cheng, 2017), and a number of important substances will be extracted from the coffee cherries. The semi-carbonic maceration process help reduce the greeny stench, and it increases the flavors of citrus fruits and spices and creates brighter acidity from the malic and critic groups (Jitjaroen et al., 2021).

Furthermore, the Yeast fermentation process has also been integrated (Jearanai, 2020) into the Coffivino process. The main idea for this integration is to create the perfect environment for the fermentation process by tailoring the type and amount of nutrients and selecting specific yeast to match the desired coffee quality. It is essential to maintain a stable temperature and quality control, such as the amount of sugar, ethanol, pH, and acid, to stop the fermentation process at the desired "endpoint" (in winemaking, this point is called "complete fermentation") (Jitjaroen, 2013; 2021).

Identity of Coffivino Process

Coffivino process can create and intensify coffee's unique characteristics, especially desirable aroma and fragrances such as floral, berries, citrus, nutty, and the soft and complex acidity of malic, tartaric, and citric acids, and finish with the natural sweetness of the coffee.

The "double anaerobic fermentation," a process that combines the leftover precursor of the first fermentation process (Coffivino process) with the newly created from that same process, will create additional aromatic and acidic substances needed for the Maillard and caramelization reactions of green bean coffee during the roasting process (Sunarharum et al., 2014).

Additionally, the carbon dioxide created during the fermentation process, both the added carbon dioxide gas during the Semi-carbonic maceration step and the ones created during the Yeast step will accelerate the degradation of mucilage, which helps decrease the stickiness and increase simple sugars, adding more sweetness to the coffee. Furthermore, carbon dioxide can enlarge the cell structure of coffee beans, resulting in faster water evaporation within the cells during the drying process, which helps reduce the drying time (Liu et al., 2014). This process helps decrease waste created through the fermentation process and decrease water and labor costs, making it eco-friendly.

Thus, the Coffivino process answers unhealthy coffee cherries caused by plantation management, irrigation, fertilization, soil, and/or climatic conditions by designing individual fermentation profiles. Furthermore, if the Coffivino process is applied to the fermentation of healthy coffee cherries, 90 plus cup scores are guaranteed.

COFFIVINO FERMENTATION PROFILE

Arabica Research Team picked Arabica coffee cherries from Pa Kia village, Chiang Dao district, Chiang Mai province, situated at 1,530 meters above sea level, for its Coffivino research project. The last crop of the 2021 harvest year was considered the least desirable crop of each year; they are mainly processed into low-quality coffee (commercial grade). The research started by testing the property of intact mucilage (medium quality level with total soluble solids of 15-16 ºBrix, and pH 4.9-5.1). The next step was choosing the most suitable fermentation profile, "Rosé Coffivino" (Rosé, a French word, which means pink-red wine). The aim was to create a specialty coffee, outstanding in its floral fragrances, complex acidity, slight Rosé winey character, great body, and a long balanced aftertaste.

The key to the Coffivino process is to control and analyze the quality of coffee cherries throughout the entire fermentation process. For example, maintaining a stable fermentation temperature, randomly analyzing the chemical properties of samples in a laboratory, and regularly conducting sensory tests by smelling and tasting. Tight control of the entire fermentation process will help avert any problems or crises that might arise during the process, such as sluggish fermentation and stuck fermentation. Furthermore, it will assist in stopping the fermentation at the right moment when the quality of the coffee cherries is at its peak (complete coffee fermentation) (Jitjaroen, 2013; 2021).

Coffivino Process Integrated with LTLH Drying Technique

The most critical step after stopping the fermentation is drying the coffee beans until they have no more than 12.5% moisture within the fruit (Coste, 1992; Instrução Normativa Nº 8, 2003). Sun drying is a long-standing traditional method, where the cherries will be exposed to the uncertain climate, intense sun, and/or rainfall. The coffee cherries are at risk of contamination and overly dehydration, which would cause the coffee cherries to shrink, leading to a low-quality aroma. It needs a lot of laborers to spread the coffee cherries. Hench, Coffivino process utilizes a drying process called "Low Temperature, Low Humidity (LTLH)." It is a great way to preserve aromas and fragrances created during the fermentation process. In recent years, LTLH has gained acceptance and popularity among industrial specialty coffee processors in Thailand (LTLH, 2021).

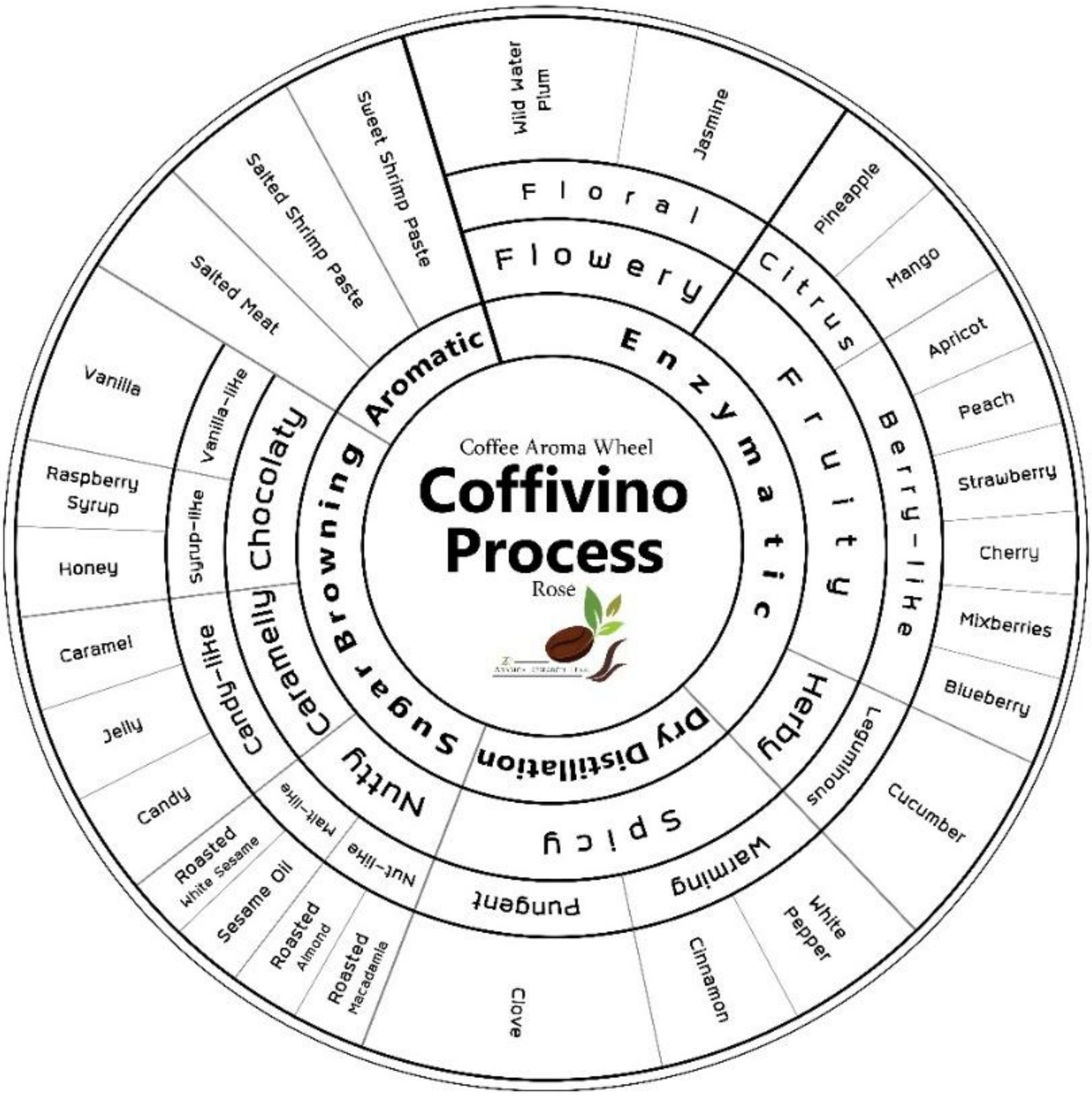

Figure 1. Coffee aroma wheel produced during Coffivino Process (CV): a new coffee fermentation technique, investigated by Gas Chromatography Olfactory (GC-O)

Coffivino Aroma Wheel

A way to confirm the type and amount of coffee aromas that have been widely accepted and cited in the research is by using Gas Chromatography Olfactory (GC-O) (Mahattanatawee, 2010). A sensory expert has discovered that the Coffivino process can create more fragrances than traditional processes (Figure 1). By considering the Enzymatic group, which has been developing while the coffee cherries were growing on coffee trees and has been further developed during the fermentation process (Lenoir, 1997), it is clear that coffee fermented by the Coffivino process possesses outstanding floral, berries, and citrus aromas, as well as a creamy body and a lingering sweetness. Due to the unique characteristic of Rosé flavor during the cupping process, Q Arabica graders have given 4-5 extra scores more than the Natural process, and roastmasters have indicated that this is a 90 plus coffee. Therefore, it can be summarized that high-quality fermentation can create a high-quality aroma (Haile and Kang, 2019). The various physiological changes of the coffee beans during the fermentation will affect the quality of precursors for coffee aromas and fragrances (Vaast et al., 2006).

CONCLUSIONS

The coffivino process is a new coffee fermentation technique, which wine fermentation technologies have inspired. Analyzing and controlling the quality of the entire fermentation process shows that the Coffivino process can create coffee with unique qualities, a wider variety of flavors, and higher intensity than the traditional process. This new technique would be the perfect solution for the fermentation of lesser quality coffee cherries on an industrial level and elevate them to the sensory quality of specialty coffee.

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Sustainable packaging review: Recent materials and technology of smart biodegradable packaging

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ABSTRACT

Plastic is widely used as product packaging. The time-consuming degradation of old plastics leads to an increase in environmental pollution. Sustainable packaging has been recently developed to decrease the problem. Along with the need to identify product quality during storage and distribution, smart biodegradable packaging is developed. The packaging not only contains and protects the product but also provides information about the rapid change of product quality. This article reviews various smart biodegradable materials such as polymer, gelatin, chitosan, or starch materials and packaging production technologies such as extrusion, compression molding, and film casting technology. The latest innovations in smart packaging are labels that can sense and record changes in food products with unique signs on the packaging. This label can detect if there is a leak in the package; the indicator will show a change. The combination of materials according to utilize an abundance of natural resources of each country and affordable technology needs to be continuously developed to produce sustainable packaging that can be produced in many countries.

Keywords: sustainable packaging, smart, biodegradable

INTRODUCTION

Plastics are the primary material widely used as packaging that can cause many environmental problems. Based on data from IMEF (2020), Indonesia produced 34.5 million tons of waste/year, and 17% of waste is plastic. Plastic that has been modified to be part of sustainable packaging is not polluting the environment. Sustainable packaging (SP) is crucial because it reduces the ecological footprint of all the stages in the product's life cycle. It helps both the producer and the consumer reduce their environmental impact. SP was developed to reduce waste using environmentally friendly materials (Magnier et al., 2016), called biodegradable packaging (BP). Ambrose (2020), BP can be an alternative because microbes easily damage the material that constructs BP. BP material is mainly in the form of a biopolymer. Biopolymers can be extracted directly from biomass such as cellulose, lignin, chitin, chitosan, wheat gluten, gelatin, casein, and protein (Spizzirri et al., 2015). The biopolymer materials discussed in this review are chitosan, gelatin, and starch because the ingredients for these materials are easy to obtain. Potential ingredients for biopolymers in Indonesia are corn, sago, soybeans, potatoes, cassava, and chitin for making chitosan in crustacean shells. Based on data from the Indonesian Central Statistics Agency in 2018, corn production was 30 million tons, cassava 19 million tons, soybean 983 thousand tons, sago 460 thousand tons, and crustacean 916 thousand tons. Applications of BP manufacturing technology include extrusion, compression molding, and film casting. This technology has been widely utilized in industrial and laboratory-scale food and beverage packaging. The four main markets for BP are food packaging, non-food packaging, disposable personal medical devices, and consumer goods (Davis and Song, 2006). This review discusses the development of smart biodegradable packaging (SBP) in terms of materials and technology and opportunities for BP innovation research in many countries.

MATERIALS AND METHODS

This paper uses a systematic review approach as the primary method of collecting and analyzing the literature (Hariyati, 2010). This article presents the latest research results from various sources related to biodegradable materials and technology that offer information for researchers in many countries to develop sustainable packaging. Literature studies and surveys on quantitative and qualitative empirical studies have been published, such as journals, books, encyclopedias, and additional information from the Australian Packaging Covenant Organization (APCO). Journals, books, and encyclopedias can be accessed at the publishers: Elsevier, Emerald Insight, Springer, Google Scholar, and Taylor & Francis Group. The search used the keywords "sustainable packaging," "smart packaging," "biodegradable packaging," "biodegradable materials and technology," and "edible film." The Literature books from international publishers. Those publications were analyzed in the period 2006-2021.

RESULTS AND DISCUSSION

Sustainable Packaging

Packaging is an extrinsic element of a product that should be effective, efficient, cyclic, and safe (Deliya and Parmar, 2012). Packaging primarily accommodates and protects products from producers to end consumers, attracts consumers, and provides product information. SP has more function to protect the environmental impact than conventional packaging (APCO, 2020). Lewis (in Robertson, 2009), Australia's Sustainable Packaging Alliance (SPA), developed four principles related to SP:

a. Effective: The system applied in the packaging process adds real value to society effectively and protects the product throughout the supply chain.

b. Efficient: Packaging systems are designed to use materials and energy efficiency throughout the product life cycle.

c. Cyclic: Packaging materials can be recycled continuously through natural or industrial systems with minimal material degradation. Recovery rates must be optimized to ensure that they achieve energy savings and greenhouse gas emissions.

d. Safe: The packaging components in the system, including materials, inks used in packaging, pigments, and other additives, possess zero risks to humans or the ecosystem.

There are ten principles for consideration of packaging design and procurement to increase SP. There is recovery design, material efficiency, design to reduce waste, eliminate hazardous materials, use recycled materials, use renewable materials, plan to minimize litter, design for transport efficiency, design for accessibility, and provide consumer information on sustainability. Recoverability of packaging refers to the availability of systems for reuse, recycling, composting, or energy recovery. Optimized or material efficiency refers to no further reductions in packaging weight or volume are possible at present. Packaging design ensures products reach their final destination without any damage or wastage, and this includes information on the label to assist consumers in reducing waste. Eliminating hazardous materials means avoiding using hazardous substances that could be toxic to humans or their living organisms. Using recycled and renewable materials in packaging helps create sustainable markets because these materials generally use less energy and water to manufacture, cost savings, and have a lower environmental impact. Design of minimizing litter aims to design any package that tends to be found in the litter stream (such as fast food and beverage packaging) to reduce the likelihood of it becoming litter. Packaging should be designed to maximize transport efficiency through lightweight, fully utilizing shipping space where appropriate. Design for accessibility Relates to the ease of using consumer experiences when completing tasks, including factors such as ease of opening and readability of labels. Providing consumer information on sustainability means providing clear information or advice about any claims made about the packaging's appropriate disposal or environmental attributes (e.g., recycled content or sustainable sourcing of materials) on the packaging or packaged product (APCO, 2020).

Smart Biodegradable Packaging

Kerry and Butler (in Wang et al., 2019) state that smart packaging is defined as packaging that provides a functional level apart from protecting, loading, and providing product information. Smart packaging refers to packaging systems with embedded sensor technology used with foods, pharmaceuticals, and many other types of products. It is used to extend shelf life, monitor freshness, display information on quality, and improve product and customer safety (Schaefer and Cheung, 2018). Smart packaging's exact function has varied solutions and depends on the packaged products, for example, food, beverages, medicines or health products, and household products (Kuswandi et al., 2011). BP is from environmentally friendly materials to be easy to recycle, and BP is nontoxic, thereby reducing carbon emissions and climate change (Ambrose, 2020). According to Davis and Song (2006), there are two objectives for developing BP: utilizing renewable energy and potential sources of raw materials and facilitating integrated waste management to reduce waste.

Smart Biodegradable Materials

Chitosan, gelatin, and starch are part of the biopolymer because biodegradable materials are from renewable resources (Spizzirri et al., 2015).

Biopolymers serve as an alternative material for environmentally friendly packaging. The advantages of using biodegradable materials are reducing fossil-based raw materials to reduce carbon dioxide release, biological degradation and reduce landfills with the possibility of applying agricultural resources to produce environmentally friendly materials. The following subsections describe biopolymers, chitosan, gelatin, and starch.

Biopolymers

Biopolymers are environmentally friendly food packaging materials because they are easily biodegradable (Tang et al., 2012). Biopolymers are natural polymers materials, including starch, cellulose, chitosan, and gelatin, which can replace petroleum-based materials (Chen et al., 2019; Elsabee et al., 2013). Food packaging is generally made of natural biopolymers from starch, cellulose, chitosan, agar from carbohydrates and gelatin, gluten, alginate, whey protein, and collagen from protein (Stoica et al., 2020). The categories of biopolymers are shown in Figure 1. and applications for SBP as shown in Table 1.

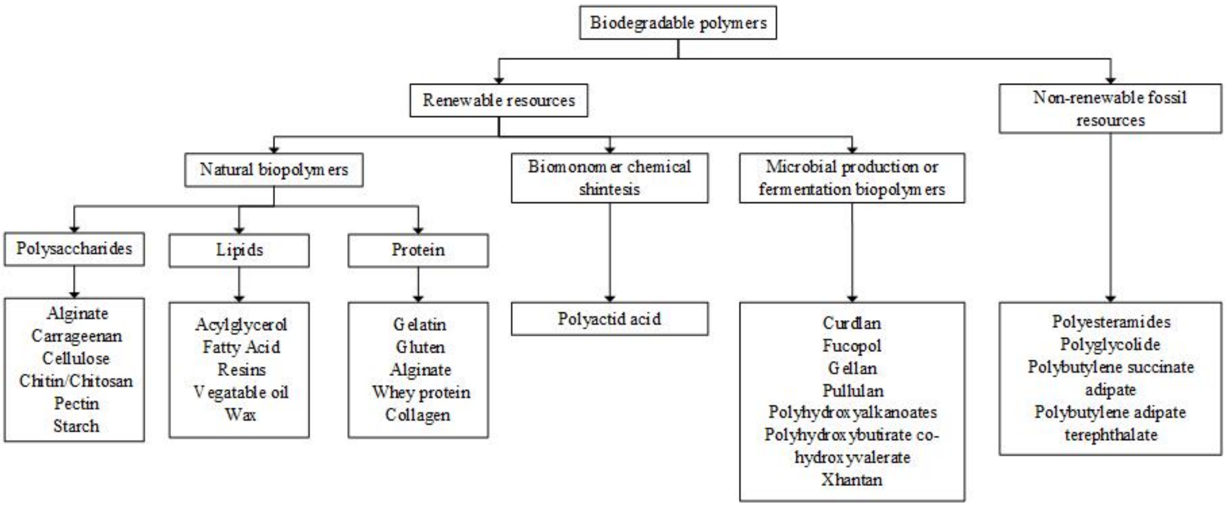

Figure 1. Biopolymer category (Adapted from Haghighi et al., 2020; Rhim et al., 2013).

Chitosan

Chitosan is a linear polysaccharide consisting of 1, 4 related glucosamine and N-acetylglucosamine. Chitosan is a natural polymer derived by the deacetylation of chitin in alkaline media (Kamkar et al., 2021), which is the second-largest polysaccharide in nature after cellulose (Giannakas et al., 2014). Chitosan has potential applications in food technology because it is biocompatible, nontoxic, decomposes in a short time, and can form a good film. Chitosan can improve mechanical, antifungal, and waterproof properties. The change in chitosan from 5% to 30% can preserve food for up to 15 days (Soltani et al., 2018). Chitosan composite film with kojic acid significantly decreased the viscosity, moisture content, water vapor permeability and increased the film's antibacterial activity (Liu et al., 2020). The biodegradable film was made by mixing guar gum, chitosan, and polyvinyl alcohol-containing mint and orange peel extract and cross-linked with nontoxic tetraethoxysilane (TEOS). Biodegradable films can degrade rapidly for six days, and it is confirmed that there is strong microbial activity in the soil (Bashir et al., 2017). The mass of film biodegradation decreases by 80% in 14 days, so that composites from chitosan have the potential to become environmentally friendly food packaging materials (Oberlintner et al., 2021; Muthmainna et al., 2019).

Table 1. Application chitosan, gelatin, starch as film.

Items	Material	Bioactive compounds	Parameter	Characteristic	Source
Chitosan	AgNO3, gelatin, polyethylene glycol, acetic acid	AgNPs (*Mimusops elengi* fruit extract)	Shelf life of fruit	Thickness: 87.60 ± 2.19 µm Tensile Strength: 21.19 ± 1.01 MPa Elongation at break: 27.23 ± 0.76 %	Kumar et al., 2018
	Polyactic acid, nanochitosan, polyvinyl alcohol, polyethylene glycol	PLA / NCS	Antimicrobial properties of films in cold conditions	Thickness: 0.075±0.02 mm Tensile Strength: 366.33 ± 0.12 Kg/cm^2	Fathima et al., 2018
	Cloisite-Na +, cloisite-Ca + 2, glacial acetic acid, glycerol and tween 80, water essential oil	Rosemary essential oil or ginger essential oil	Shelf life in cold conditions	Thickness: 40 to 70 µm	Pires et al., 2018
	Glacial acetic acid, hexadecyl-trimethylammoniumbromide and (CTAB)	Curcumin	Inhibition against *Staphylococcus aureus* and *Escherichia coli*	Thickness: 0.0931 ± 0.0021 mm Tensile Strength: 19.87 ± 1.02 MPa Elongation at break: 25.46 ± 2.16 % Water vapour permeability: 15.21 ± 1.83 g 10−11/sm^2 Pa	Wu et al., 2019
	Methylcellulose powder	Red barberry anthocyanins	pH-indicator and halochromic	Thickness: 0.130 ± 0.008 mm Tensile Strength: 45.05 ± 0.55 MPa Elongation at break: 16.05 ± 0.07 % Water vapour permeability: 2.35 ± 0.05 g 10−11/sm^2 Pa	Sani et al., 2021
Gelatin	Bovine gelatin, glycerol	Red cabbage	pH indicators	Thickness: 58.2 ± 5.9 µm Moisture content: 21.3 ± 0.6%	Musso et al., 2019
	Gelatin, glycerol	Cashew gum powder	Biodegradability assay	Thickness: 67 ± 0.02 mm Tensile Strength: 82.56 ± 0.06 MPa Elongation at break: 114.90 ± 24.54 % Water vapour permeability: 1.84 ± 0.13 g.mm.k.Pa^{-1} h^{-1}m^{-2}	Oliveira et al., 2018
	Starch, sorbitol	*Tetradenia riparia* extract	Antimicrobial activity and antioxidant activity	Thickness: 0.378 ± 0.010 mm Tensile Strength: 7.48 ± 0.283 MPa Elongation at break: 34.1 ± 0.598% Water vapour transmission rate: 11.3 ± 0.651 g h^{-1}m^{-2}	Friedrich et al., 2020
Starch	Cassava starch, glycerol	Green tea and basil	pH indicator, degraded in soil and thermal stable	Thickness: ~0.25 mm Water vapour transmission rate: 3.4 ± 0.2 g^{-10}s^{-1}m^{-1}Pa^{-1}	Medina-Jaramillo et al., 2017

Continued

Table 1 (Continued).

Items	Material	Bioactive compounds	Parameter	Characteristic	Source
	Starch, xanthan gum and glycerol	Sodium hypophosphite and citric acid	thermal and microstructural properties	Thickness: 430 ± 32 μm Tensile strength: 2.23 ± 0.24 MPa Strain at break: 99.49 ± 15.08 % Water vapour transmission rate: 2.0 $g^{-10}s^{-1}m^{-1}Pa^{-1}$	Simoes et al., 2020
	Brown rice starch, chitosan, glacial acetic acid, Refined, bleached and deodorized palm oil	-	Antiomicrobial and biodegradability	Thickness: 0.22 ± 0.022 mm Tensile Strength: 15.2 ± 0.432 Mpa Elongation: 34.7 ± 1.15 %	Hasan et al., 2020
	Cassava starch, chitosan, glycerol, distillated water	*Eugenia uniflora L.* leaf extract and / or natamycin	Physical properties, antioxidant and antifungal activities of films	Thickness: 0.080±0.004 mm Tensile Strength: 13.3±1.4 MPa Elongation at break: 2.8±0.7 % Water vapour transmission rate: 1.98±0.38 10^{-8} g.mm/h. cm2.Pa	Chakravartula et al., 2020

Gelatin

Gelatin is a protein resulting from partial hydrolysis of collagen at controlled temperature and pH (Leite et al., 2020). Gelatin has low barrier properties against moisture and poor mechanical strength, so adding natural additives such as pure compounds, essential oils, and plant extracts are necessary. Natural additives also function as antimicrobials and antioxidants in biopolymer films (Rhim and Kim, 2014). Gelatin-based film mixtures with different properties show that gelatin forms a great layer (Suderman et al., 2018). The cross-linking effect of phenolic and gelatin substances increases cross-linking of proteins with the concentration of oxidized phenolic compounds, resulting in a tighter and stiffer film structure (Choi et al., 2018). Gelatin film containing a synthetic acid-base indicator (methyl orange, neutral red, and green bromocresol) or natural (curcumin) has changed color when contacted with gaseous, liquid, and semi-solid media with different pHs. This serves as an indicator of change or food spoilage because there is a response to the growth and metabolism of microorganisms that evaporate during storage (Musso et al., 2016).

Starch

Starch is one of the natural biopolymers available in abundance, nontoxic, and forms films (Azevedo et al., 2017). Starch is formed into a thermoplastic substance with low mechanical properties, poor safety against oxygen and moisture content. The molecule consists of d-glucose polymers: amylose (20% –30%) and amylopectin (70 –80 %), depending on the source, and have different proportions (Rydz et al., 2018). Mixing composted polyester, polybutylene succinate, poly-caprolactone with starch less than 50% increases water resistance, improves mechanical properties, processing, and has biodegradation properties (Ahmadzadeh and Khaneghah, 2019). The main ingredients utilized in food packaging are mixed with starch due to components actively transmigrating (Ivankovic et al., 2017). In Indonesia, biodegradable plastics made from sago starch and cassava have considerable potential to be developed as environmentally friendly packaging materials (Kamsiati et al., 2017).

Smart Biodegradable Technology

Technology for creating plastic or edible films is multiple to support a sustainable environment. Some of the technologies used are extrusion, compression molding, and film casting. These technologies are efficient and fast for producing plastic packaging or edible film to be applied on an industrial or laboratory scale. The following subsections explain more about extrusion technology, compression molding, and film casting. The technology applications of extrusion, compression molding, and casting film are shown in Table 2.

Table 2. Application extrusion, compression molding, and casting film.

Technology Process	Application	Attribute	Source
Extrusion	Starch / PBAT nanocomposite films	Tensile strength: 7.4 Mpa Thickness: 40–50 µm	Zhai et al., 2020
	Poly (butylene succinate) biocomposites	Tensile strength: 78.1 Mpa Thickness: 1.8-2.1 mm	Zhao et al., 2020
	Starch-based nanocomposite films	Vertical tensile strength: 3.07 Mpa Horizontal tensile strength: 3.83 Mpa	Gao et al., 2019
	Starch / chitosan-based composites	Tensile strength: 0.6 ± 0.1 Mpa Thickness: 617 ± 29 µm	Llanos et al., 2021
	Active meat packaging from thermoplastic cassava 1starch-containing sappan and cinnamon herbal extracts	Tensile strength: 11 Mpa and 9 Mpa Thickness: 0.06 mm and 0.05 mm	Khumkomgool et al., 2020
	Cassava starch and anthocyanins	Tensile strength: 0.4 ± 0.0 Mpa Thickness: 1.5 ± 0.2 mm	Vedove et al., 2021
Compression molding	Active fish gelatin films with anthocyanins	Tensile strength: 41.3 ± 2.7 Mpa	Uranga et al., 2018
	Poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) and Poly-thylenglycol	Tensile strength: 22 ± 3Mpa Thickness: 0.0025 mm	Requena et al., 2016
	PHBV / PBAT-based nanocomposite films with organically modified nanoclay	Tensile strength: 15.31 Mpa Thickness: 150–200 nm	Pal et al., 2020
	Edible Films Production from *Canavalia enciformis (L.)* Flour	Tensile strength: 4.091 Mpa Thickness: 0.302 mm	Lindriati and Arbiantara, 2011
Casting film	Kaolin (Kln) and silver-kaolin (Ag-Kln) in gelatin-composite films	Tensile strength: 3.51 ± 0.18 Mpa Thickness: 89.00 ± 1.00 µm	Najwa et al., 2020
	Poly-vinyl alcohol / starch / glycerol / citric acid composite films	Tensile strength: 14 MPa Mpa Thickness: 635 µm	Das et al., 2019
	Lindur fruit starch with addition of glycerol and carrageenan	Tensile strength: 132.88-168.33 kgf / cm^2 Thickness: 0.13-0.20 mm	Jacoeb et al., 2014

Extrusion

Extrusion is a technique in the field of materials science by applying it to starch films. The compression and extrusion technique is faster and more efficient so that it is suitable for the industrial-scale production of plastics. Using a thermo-mechanical process can accelerate output, reduce production time and costs, thereby increasing process effectiveness (Nilsuwan et al., 2019). Extrusion is done by a single screw extruder, as shown in Figure 2.

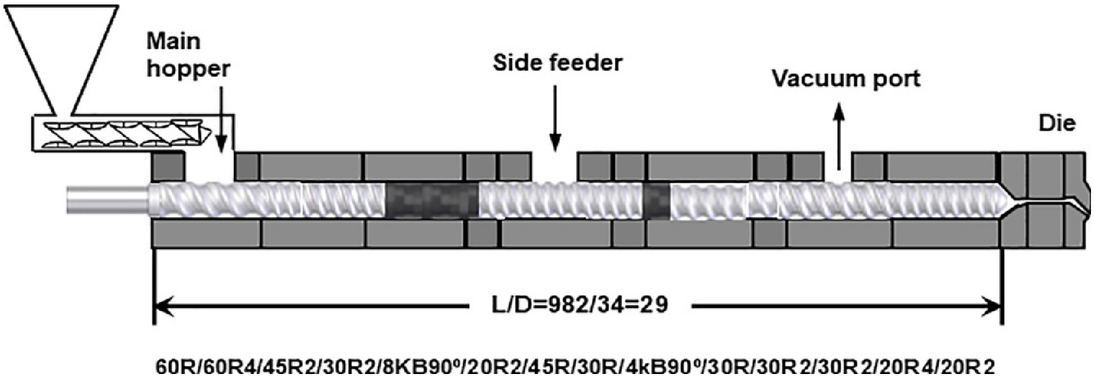

Figure 2. Cylindrical extruder with screw configuration (Torres-Giner et al., 2018).

The continuous process is advantageous because it uses high pressure and temperature. The extruder has a thread diameter of 27 mm and a length/diameter ratio of 48:1 (L/D) at a constant temperature at 180ºC with a screw speed and feed speed of 100 rpm and 5 kg/hour. Allows the extruder to have reactor-like properties, so that processing conditions depend on the characteristics of the polymer mixture, reactive extrusion (REx) can be achieved (Gutierrez et al., 2017; Gutiérrez and Alvarez, 2018). Pellets (90g/film) are then pressed using a hydraulic press at 130°C and 5 × 106 Pa (50 bar) for 10 minutes, after which a cooling cycle was performed before being applied to a temperature of 30°C. The resulting material was labeled, and the film was conditioned under controlled relative humidity (RH, 57%) for a week at 25°C (Julien et al., 2019).

Compression Molding

Compression molding is a plastic forming process that requires less space and time so that more efficient and continuous. Compression molding can be applied to edible films forming with pressure affecting thickness, color value, elongation, tensile strength, and WVTR (Lindriati and Arbiantara, 2011). Filming with compression molding techniques is prepared by the melt blending process and compression molding (Menzel, 2020). The ingredients are mixed for 15 minutes on a roll in the film-forming, which is previously heated at 55ºC until homogenous. It is pressed with compression at a temperature of 80ºC and 300 bar, obtained a rectangular sheet with an average thickness of 1.30 mm (Andonegi et al., 2020).

Casting Film

The casting method is widely used because it is the simplest method to create biopolymer films. The application of casting film to food products fulfills food safety, maintains quality, and increases shelf life (Priyadarshi and Rhim, 2020). Soltoni et al. (2018) showed that single-layer films were formed using the casting film technique. Chitosan was dissolved in 10 ml of 2 v/v% acetic acid solution under stirring to produce a transparent solution. The nanocellulose gel was dispersed in 20 ml deionized water and sonicated (200 W) during the resulting homogeneous dispersion. Then 3.99-10% of gelatin polymer is added to the solution. Previous treatment on gelatin is heated and stirred until dissolved. Subsequently, it was mixed at a temperature of 45ºC and ultrasonication (50W) for 2 minutes. The final solution was dried in an oven at 55ºC for 12 hours to form a film. In this method, protein or polysaccharides are dispersed in a mixture of water and plasticizer or hydrocolloids in starch, glucomannan, or carrageenan, and plasticizer.

CONCLUSIONS

Innovative biodegradable packaging (SBP) has a big role in protecting the environment. Naturally, biodegradable packaging is expected to be an integral part of life. SBP material sources include chitosan, gelatin, and starch. Many potential ingredients to be developed into biopolymers are corn, sago, soybeans, potatoes, cassava, and chitin in crustacean shells. Rapid technological developments, such as extrusion, compression molding, and film casting, can be utilized to produce SBP. It is crucial to introduce biodegradable polymer materials and technologies. SBP continues to grow, and the discovery of new, more effective technologies, integration between technologies, and production scale doubling up to be cheaper. The availability of materials according to natural resources and affordable technology can be utilized to produce SBP in the future.

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Precision feeding management: New approach for better and more sustainable livestock production

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ABSTRACT

The demand for livestock products increases continuously and cannot be avoided; on the other hand, the total livestock production is still lower than the demand. The problem has recently become more complex, as the demand for livestock production must produce not only enough quantity but also high quality and healthy products for the consumers, create welfare for the livestock, be safe and friendly for the environment, and be highly sustainable for our next generation. All of these demands must be strongly related to the efficiency of feed utilization by the livestock, as feed is the major input for the livestock to maintain its life and production processes. Hence, precision feeding management must become an excellent approach to overcome all of the problems. Precision feeding is an attempt to maximize feed utilization by livestock by supplying the most appropriate nutrients to the livestock. Thus, in this approach, livestock is expected to consume less feed, digests, and metabolizes the feed very much effectively, and then excretes less waste. Those higher efficiencies of feed utilization by livestock must consequently give some advantages, including 1) minimize the amount of feed offered and reduce refusal feed by the livestock; hence the available feeds can be used to rear more the number of livestock to multiply livestock products, 2) increase livestock productivity with less feed cost, hence increase profit for the farmer, 3) reduce livestock waste including feces, urine and also ammonia and methane gas, hence make a better of environment, and finally, all of those advantages must lead more sustainable livestock production systems.

Keywords: precision, feeding, farming, environment, sustainability

INTRODUCTION

The agricultural sector is the most crucial enterprise on this planet. Almost all developed or developing countries and agricultural or industrial countries have the agricultural sector as their enterprises. Each country must have a national agricultural institutional responsible for developing the agricultural sector as there is also one of the Specialized Agencies in the United Nations (UN) called as Food and Agriculture Organization (FAO). This is because almost entirely the requirements of living organisms, most notably for humans, are from the agricultural sector. The agricultural sector is the only and essential source of foods for human beings and other organisms in plant and animal origin foods. In addition, the farm sector also supplies some other important requirements, including the source of income, clothing, housing, medicine, recently for renewable energy (fuel). Hence, agricultural products are the essential commercial commodities in the world. The biggest world trade is for agricultural commodities, especially for food, feed, and fuel. On the other side, the agricultural sector has direct inter-independency with nature, where the agricultural sector must be influenced by the natural conditions and vice versa, the agricultural sector must influence the nature conditions. It means that good agriculture practices will improve or at least keep the natural condition that finally enhances or at least keep the conditions of the agriculture itself. Bad practices of agriculture will degrade land and environmental conditions that finally also degrade the agricultural itself.

Livestock production is one of the sub-sector of the agricultural sector, and this involves livestock as the main agent of producers. In addition to the functions of the agricultural sector for human beings as mentioned above, livestock also has the role as labor for transportation or land cultivation, an organic fertilizer producer, perfect saving, culture, religion or ceremony, symbol of wealth or social status, and souvenir. However, livestock production has been blamed for having a considerable contribution to environmental pollution (land, water, and air), greenhouse gas (GHG) emissions that cause global warming, and environmental degradation, especially land degradation due to land clearing (deforestation), especially for planting feed and fodders. Livestock production has also been blamed for being the potential to transmit some zoonotic diseases, including food and moot disease (FMD), anthrax, bovine spongiform encephalopathy (BSE) or mad cow disease, verotoxigenic E. coli (VTEC), chronic wasting in cattle, recall of penicillin containing consumption milk, and avian/swine influenza (Thomson, 2003; Noordhuizen and Metz, 2005). Livestock products potentially contain residual antibiotics and growth promoters due to the widespread use of those feed additives in animal production.

Feed and feeding management is also known to have a negative impact on agricultural resources, the environment, and sustainability. This is because most aspects of feed and feeding management are the potential to cause unsustainable conditions. The unsustainable conditions are mostly due to land and environmental degradation and pollutions. The first aspect is the way of feed provision, feed sources, and feed selection to be included in the diet. The second aspect is how feeds are prepared for livestock, including feed processing, feed formulation, mixing, and feeding to livestock. The third aspect is how efficient the feeds are utilized by livestock, including feed consumption and its efficiency of digestion, metabolism, and conversion into livestock products.

Feed is the most abundant input in animal production that must be supplied every day. Intensive production of feeds that are mainly from plants origin has been reported by many authors to cause land and environmental damage, especially caused by land use, land clearing, deforestation, especially for soybean and maize production, and also for pasture or grazing land (Thornton and Herrero, 2010; Macedo et al., 2012; Eshel et al., 2014; Clark, 2012). Depends on quality, palatability, and amount of feed offered, part of feed provided to livestock are wasted as rejected and unconsumed, or refusal feeds. The presence of refusal feed must increase the requirement of feedstuffs in animal production and must increase the need to improve feedstuffs production. In addition, at least 60% of consumed feeds by livestock are wasted and excreted back to nature as feces, urine, gas, heat, and sweat as by-products during feed digestion and metabolism processes. Feed waste production must cause pollution to the environment and global warming. An only a small part of consumed feeds by livestock are utilized, retained, and converted to livestock products. For example, broilers deposit body fat and protein that together represent 35 to 40% of their daily ME intake (Lopez and Leeson, 2005), and less proportion was reported for protein. Cerisuelo and Calvet (2020) reported that the environmental impact of feedstuffs production and feeding management in monogastric animal production is mainly due to the production of feedstuffs and manure or waste management.

Based on the positive and negative aspects of agriculture or livestock production, thus agriculture or livestock production must be managed and operated as well as possible to sustain and maximize its essential functions and minimize its negative impact on life and the environment. For those, this paper discusses the current and future conditions of supply and demand for livestock products and production and strategy to bright the balance between both supply and demand, especially from a feeding management point of view.

SUPPLY AND DEMAND FOR LIVESTOCK PRODUCTION AND IT PRODUCTS

Different kinds of livestock products as food are the second major important foodstuffs after plant origin foodstuffs. Livestock products are considered to have higher quality and price compared to plant-origin food. Livestock products are mostly regarded as good protein sources and have good taste. The protein of animal origin shows high digestibility and contains very good amino acids composition in respect of human amino acids requirement with amino acids score of more than 90%. (Rosegrant et al. (2009) reported that 33% of the total world protein consumption is from livestock products.

The demand for livestock products as food has increased continuously and cannot be avoided. This is because of the continuous increase of the human population, the increase of their income and buying capability, and their awareness of a higher quality of food. The increase has especially happened in the developing countries, which is three times higher than those in the developed countries (Delgado et al., 1999). This is because the consumption of livestock products by people in the developed countries has been very much higher as compared to those in developing countries. However, the total world consumption for livestock products has never been balanced with the total of livestock production (Food and Agriculture Organization, 2011).

With regards to the deficit of the world livestock products in respect of the requirement, there are at least three general causes for these conditions. Those are due to the low world livestock population and productivity. In addition, the world livestock population and their productivity are not well distributed all over the world. The bigger scale of livestock production, higher population, higher application of technology, and higher production rate or productivity of livestock are mostly concentrated in developed countries and to a lesser extent in developing countries. Moreover, the accessibility of people to livestock products is also higher in developed countries than in developing countries. Consumption of livestock products in some developing countries is still below the requirement due to the lack of livestock products supply and less accessibility of the people in those countries to the livestock products.

The above problem of demand for livestock products has recently become more complex in the last few years. The need for livestock production is not only to produce a sufficient quantity of products as food but also requires high quality, safe and healthy products for the consumers, welfare conditions for the livestock, safety and friendly for the environment, and highly sustainable for our next generation.

It is recently the trend in lifestyle and food consumption by people. The consumers increase not only their quantity consumption of livestock products, but they also need healthy and high-quality livestock products. Especially for meat, the consumers need tender meat with low-fat content and better fatty acids components, mainly for red meat. Meat with such characteristics is considered to be better for health especially to prevent coronary artery disease or heart attack, and good for children's intelligence. Milk protein and fat content are used as milk price determinants. Milk with higher protein and/or fat content has a higher price bonus (Da Cunha et al., 2010; Edwards et al., 2019). Jayakumar and Loganathan (2015) reported that out of 50 respondents at Edamalaippattipudur in Tiruchirappalli District, 48 percent and 44 percent of the respondents purchased milk because of the quality and the taste of milk, respectively. Consumers were reported to prefer purchasing broiler with dark yellow to light orange color and egg with orange to dark orange egg yolk color. Omega-3 fatty acids containing egg and also organic livestock products have been preferred by consumers in the last few years due to their several advantages for health and intelligence. With regard to safely livestock food origin, the use of antibiotics and other additives or implants to improve livestock performance and the use of mycotoxins contaminated feeds have been given serious attention and investigation by vets to minimize or avoid the presence of their residues in livestock products which dangers not only to the livestock especially in case of the use of contaminated feeds but also to the consumers.

For the same reason of safely livestock food origin for consumers, some countries banned animal origin feedstuffs from suspected countries for endemic animal diseases, especially for anthrax and bovine somatotropic encephalomalacia (BSE) and feedstuffs containing genetically modified organisms (GMO). For those, a kind of government institution like the Food and Drugs Agency presents in almost all countries. The agency is responsible for investigating and controlling the distribution of foods and drugs containing any dangerous element for the consumers.

Like other agriculture sectors, livestock production is an enterprise that relates directly to land and water resources, so that livestock production has a high potential to affect land and water environmental conditions and vice versa. Iqubal (2013) reported that livestock production utilizes + 29 % of the total world land surface, mostly for grazing land and for growing crops as fodder or feed, and only a small part is for a farm. While Meek (2019) reported little bit higher data where livestock operations occupy 45 % of the global surface area, and an additional 10 percent is dedicated to growing feed crops for that livestock. Livestock production has been blamed for contributing to environmental degradation and pollutions. Land degradation caused by livestock is due mainly to deforestation or clearing forest trees and vegetation, and the land is then used as grazing land and for growing crops as fodder or feed. It is reported by Food and Agriculture Organization (2006) and Jarvis et al. (2010) that annual deforestation rates of world tropical forest increased between 2005 and 2010 by 8.5% and resulted in an average loss of 10.4 million hectares of forest per year. The effects of deforestation, including loss of biodiversity, cause climate change, increase greenhouse gas emissions, and reduce soil capacity in holding and saving water that causes flooding, soil erosion, and land sliding. Deforestation for livestock productions takes place mainly for growing feed or fodder crops and also for grassland.

Livestock production was reported to contribute to greenhouse gas (GHG) emissions that is the main element causing global warming or glasshouse effect with the estimate ranges from 14.5 percent of annual worldwide GHG emissions to 51 percent (Food and Agriculture Organization, 2006; Goodland et al., 2009). The contribution of GHG emission from livestock production is mostly due to deforestation for growing feed or fodder crops and grassland, and the production by microbial rumen fermentation of ruminant animal which then excreted directly to the air via eructation. Some part of methane gas is also excreted via feces or excreta of all livestock. In addition to methane gas, other pollutants from livestock waste are in the form of microorganism, nitrates (N_2O), phosphor and sulphur. A part of these pollutants especially the last three components are absorbed by the soil and utilized by vegetations in the different rate of utilization depend on type of land or soil and type and intensity of vegetation. Another part of the pollutants continues to seep into the underground and polluting groundwater or leaks into the river, polluting river, dam, lake, stream water and other wider area. Ground water is common source of drinking water for human being. Some of nitrates are also released to the air as ammonia and cause acid rain in some area of densely livestock populated area (Das et al., 2007; Dopelt et al., 2019)

Based on the above conditions, environmentalists stated that livestock production is still far from sustainable. Many widely used livestock production methods do not satisfy consumer requirements for a sustainable system (Broom et al., 2013). Distribution of world large-scale livestock production is also concentrated mostly in the developed countries, and people accessibility to livestock products is also higher in developed countries than in the developing countries.

FEED UTILIZATION PROCESS BY LIVESTOCK AND SOME LOSSES (WASTES)

Based on the problems of demand for livestock products as mentioned in the above chapter, the conditions must be strongly related to the feeding method to livestock and how efficiently the livestock utilize the feed. Feed utilization processes by livestock and their efficiency are described below and diagrammatically in Figure 1.

Livestock need to consume enough feed that contains all nutrients with the good proportion as they are required for better production. The feed nutrients are then digested in the digestive tract into simple nutrient compounds ready for absorption from the digestive tracts by the bloodstream via the wall of digestive tracts. By the bloodstream, the absorbed nutrients are distributed to all body tissues for metabolism processes. The metabolized nutrients are then utilized for maintenance to maintain life and body condition as the priority. Any excess metabolized nutrients for maintenance are then utilized to perform livestock production.

In fact, only a small portion of feed provided to livestock is really utilized by the livestock for their body condition and live maintenance as well as production. A major part of the feed is wasted by livestock in the form of refusal or not consumed feed, undigested feed, which is then excreted in the feces, and metabolic by-products, which are excreted as urine, heat, sweat, and expiration. In addition, especially in ruminant animals, a part of the feed is also wasted during feed digestion and fermentation in the rumen as heat and gas, mainly CO_2 and methane. The last three wastes are also produced during feed digestion and fermentation in the large intestine of all animals. All the wastes are only potentially causing feed nutrients and economic losses but also environmental pollution and degradation.

So that, with regards to the problems of demand for livestock products as mentioned in the previous chapter, there must be two aspects related to feed utilization processes by livestock that must be optimized. The first is to maximize the proportion of feeds that are really utilized by the livestock for maintenance and especially for the production. Then this must increase the productivity of livestock. The second is to minimize the proportion of wasted feed by livestock, including refusal or not-consumed feed, undigested and unabsorbed feed (feces), digestion, and metabolite by-products (gas, heat, urine, and sweat). Those feed losses do cause not only nutrients losses but also cause economic losses, environmental pollution, and degradation, leading to unsustainable livestock production to provide livestock products.

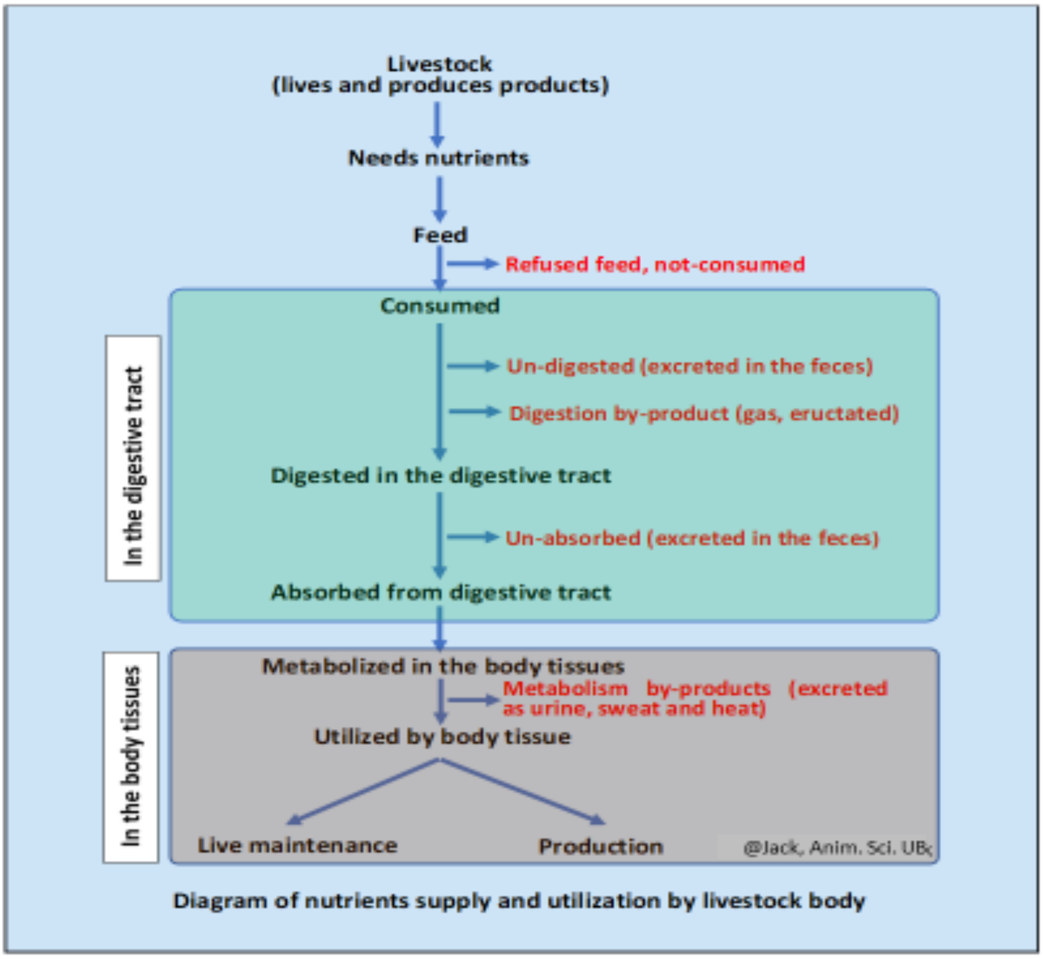

Figure 1. Diagram of feed and nutrients supply and utilization by livestock body

PRECISION FEEDING AS A GOOD APPROACH TO OVERCOME THE PROBLEM OF DEMAND FOR LIVESTOCK PRODUCTS

Feed is the major input in livestock production from which the livestock get their daily supply of nutrients for their life and production. In addition, feed is also the major cost in livestock production that determines mostly the profit in livestock production. On the other side, feed is always the most constraint and is the most challenging for developing livestock production due to its lack of availability and quality, because of the limited availability and the conditions of land and natural resources as feed sources, ongoing climatic changes. Almost entirely feedstuffs for livestock production are from plants origin either as whole plant organs (as forages in ruminant animal production), main plant products (grains and tubers as main feedstuffs in non-ruminant animal production or as a feed supplement in ruminant animal production), or industrial by-products of plant main products processing (SBM, DDGS, CGM, CGF, brewer meal, cottonseed meal, oil palm meal, copra meal, oil seeds meal, etc. as a feed supplement in both non and ruminant animal production). The second major of feedstuffs is from animal origin, especially as industrial by-products of animal products processing (fish meat, MBM, meat meal, blood meal, animal fat, etc.) as a feed supplement in both non and ruminant animal production. The third as minor feedstuffs are natural origin especially mineral as a feed supplement in both non and ruminant animal production. All feed resources are subjected to availability and the conditions of land and natural resources as feed sources, ongoing climatic changes. The costs of all conventional feed resources such as soybean meal and fishmeal are very high, and their availability in the future will be limited. In addition, the increase of food-feed-fuel competition also contributes to the reduction of feed availability for livestock production. Hence, better and most efficient utilization of feed resources for livestock production must be one of the strategies to overcome the problem. Higher efficiency of feed utilization by livestock must consequently give some advantages, including 1) minimize the amount of feed offered and reduce refusal feed by the livestock, 2) increase livestock productivity with less feed cost, hence increase profit for the farmer, 3) reduce livestock waste including feces, urine and also ammonia and methane gas, hence make a better of environment, and finally, all of those advantages must lead more sustainable livestock production systems.

Precision feeding management is an attempt to maximize as much as possible the efficiency of feed utilization by livestock by supplying the most appropriate and precise feeds and nutrients to the individual or group of animals in a farm (Pomar et al., 2019). For those in precision feeding, all genetic and environmental factors that affect the utilization of feed and nutrients by livestock must be considered based on real-time monitoring. Also, in precision feeding, all related science (including biology, physiology, microbiology, genetic, breeding, reproduction, chemistry, biochemistry, physic, math, health/medicine/immunology), technology and equipment including tools to monitor genetic and environmental factors, sensors, information, and communication technology (ICT) must be incorporated in system construction and application of precision feeding. Many papers discussing all of those factors, science, technology, and equipment and their use in precision feeding were published (Banhazi et al., 2012; Berckmans, 2014; Pomar et al., 2019; Andretta et al., 2018; Halas and Dukhta, 2020; Piccioli-Cappelli et al., 2019; Pomar Cândido et al., 2009; Zuidhof, 2020). Babinszky and Halas (2009); Banhazi et al. (2012) described in the diagram the relations of related science and technology in precision feeding as described in Figure 2.

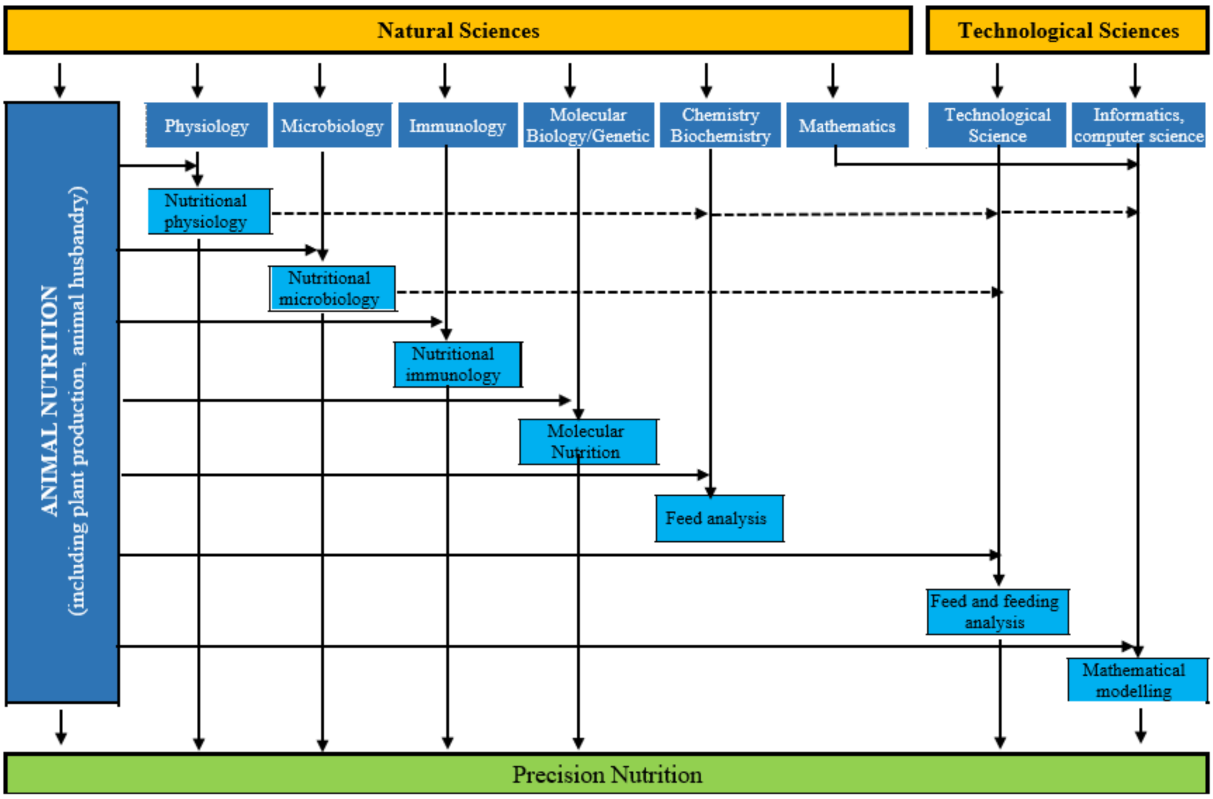

Figure 2. Relationship between natural, nutritional sciences and other related disciplines (Rewritten from Babinszky and Halas (2009); Banhazi et al. (2012))

Precision feeding is a part of precision livestock farming (PLF) that aims to offer a real-time monitoring and management system that focuses on improving the lives of the animals by warning when problems arise so that the farmer may take immediate action to overcome the difficulties. In the PLF, continuous and fully automatic monitoring on the whole farm is practiced to collect real-time information and data about essential aspects of the running farm (Berckmans, 2014; Pomar et al., 2019). The collected information and data are then analyzed, and conclusions are withdrawn to be used to improve animal health, welfare, and production and reduce the impacts on the environment at the right time. Pomar et al. (2019) defined precision feeding as a feeding technique that allows the proper amount of feed with the suitable composition to be supplied in a timely manner to a group of animals or to individual animals in a group. By precision feeding management, livestock is expected to require and consume less amount of feed, then digests and metabolizes the feed very much effectively, utilizes as efficiently as possible for maintenance and production, and excretes less amount of waste.

Precision feeding management must take an essential role in overcoming the deficit of livestock products by increasing the production and supply of livestock products. Precision feeding management that accurately considers the feed requirement of individual livestock in real-time must supply the most appropriate nutrients for higher productivity with lower feed cost and higher feed efficiency. With high efficiency of feed utilization; hence, the available feed resources can be used to rear a larger population of livestock or increase livestock population. Both livestock productivity and population are two main factors that determine the total production of livestock products. The entire production of livestock products results from the multiplication of the total livestock population by livestock productivity. Increasing livestock productivity has been the main concern in every livestock production system since livestock domestication has been done. All of the efforts, researches, and technologies in all aspects of livestock production, including livestock breeding, feeding, management, reproduction, and health, are continuously designed, tested, and some implemented in livestock production systems with the final target to increase livestock productivity. In addition to the efforts of maximizing livestock productivity, expanding the world production of livestock products through increasing livestock population must have a bigger impact on the increase of the world production of livestock products. Increasing productivity of livestock gives effect on the increase of production of livestock products by the additional scheme, but increasing livestock number or population must give effect on the increase of production of livestock products multiplier scheme. Thus, to increase the total production of livestock products, both livestock productivity, and livestock population has to be increased in a simultaneous way.// However, as a consequence of the increase in livestock population, it must also cause multiple increases in the requirement of feed and other resources for livestock production. For those, better distribution of world livestock production systems all over the world, mainly into countries with low livestock population, has to be done. The distribution includes distribution of livestock population, resources, management, productivity, and the market as well as application of technology in livestock production systems. The distribution must increase the chance of increasing the number of livestock populations all over the world by maximizing the utilization of locally available resources in each area. Finally, the distribution will increase not only the total production of livestock products but also lead to the distribution of better utilization of available resources (land, labor, and feed) for livestock production, distribution of income and wealth for most people, distribution of the supply of livestock products and access. In addition, the distribution will also avoid the overutilization of natural resources for livestock production systems and its impact on land degradation and environmental pollution in certain areas or countries.

To satisfy the demand for livestock products, it is recently not only focused on its quantity but also on its utility and accessibility, where the three focuses are called as three pillars of food security. The quantity means the total production of livestock products that are ready for the consumers. Utility pillars include quality or nutrient content, safety, and healthy of the livestock products. Accessibility pillars include well distribution, availability and stability of livestock products, and consumer access to the products. Due to the increase of consumer's need for a better quality of livestock products, then some attempts have been made to produce such high quality, safety and healthy of livestock products. Several researches have reported accurately feed modification to improve quality or modify the composition of livestock products, e.g., fat, protein, and fatty acids, especially polyunsaturated fatty acids, including omega-3 fatty acids content.

It was reported by many authors that in addition to the livestock wastes as excreted by livestock during utilization processes of feed by their body, the major causes of environmental pollution and degradation from livestock production is due to deforestation and land utilization for providing sufficient feed. Then the use of non-conventional feed resources to feed livestock by precision feeding management must reduce the negative impact of livestock production on further environmental and land degradation. Such non-conventional feed resources are agricultural and industrial by-products, insect and larvae as the feed protein source. The feed resources represent an important human-inedible feed resource for livestock production (Chenost, 1990; Devendra and Sevilla, 2002; Vasta et al., 2008;

Makkar et al., 2014; Amata, 2014; Ncobela and Chimonyo, 2015; Salami et al., 2019).

Another advantage of precision feeding to livestock is the improvement of livestock welfare. Livestock is reared not only to attempt to produce useful products for human beings, but their welfare must also be another concern by farmers. Livestock welfare has become word concerned in the last few years, as stated in Animal Welfare Act 2006 (Dawkins, 2006; Broom, 2011; Cook et al., 2015). According to the Act, livestock must be reared in as comfortably as possible to support the livestock in producing useful products in most welfare conditions. As stated in Section 3 point 1 of the Act, animals shall be given sufficient feed and water and adequate care. Feeding stuff and water must be of good quality and appropriate for the species of animal that is being fed. Thus, precision feeding, where livestock is fed a sufficient amount of feed with a good composition of nutrients required, must comply with livestock welfare as stated in the Act. At least the livestock will not suffer from hunger, nutrient deficiency, and feed-borne diseases. // Precision feeding, with its main focus on maximizing as much as possible the efficiency of feed utilization by livestock, has been reported by many authors to support more sustainable livestock production. With maximum feed utilization efficiency, livestock will convert and deposit the feed as maximum as possible into products with minimum cost and minimize as much as possible the excretion of wastes. With those three advantages of precision feeding focus, all three pillars of sustainability, i.e., sustainable environment, social and economy or planet, people and profit must be achieved (Banhazi et al., 2012; di Virgilio et al., 2018; Lovarelli et al., 2020). For social and economic sustainability, precision feeding must increase livestock production and supply livestock products more efficiently. Increasing livestock production must also serve more people for job creation and income distribution to reduce poverty. This is because livestock production has a long and complex supply and utilization chain. Anonymous (2020); Molina-Flores et al. (2020) stated that the livestock sector is a pillar of the global food system and contributes to poverty reduction, food security, and agricultural development. According to the FAO, livestock contributes 40% of the global value of agricultural output and supports the livelihoods and food and nutrition security of almost 1.3 billion people. Livestock is an important asset for vulnerable communities. Globally, around 500 million pastoralists rely on livestock herding for food, income, and as a store of wealth, collateral, or safety net in times of need. Thus, sustainable livestock production must potentially serve for a better life for most world human population as the source of food, income, and other functions and advantages of livestock production for a human being. For environmental sustainability, precision feeding management must take an important role towards a sustainable environment at least in two ways, i.e., decreasing land and environment due to feedstuffs provision for livestock and maximizing feed utilization or reducing feed waste by livestock. Pomar and Remus (2019) reported that precision feeding management reduced significantly costs of production (>8%), protein and phosphorous intake (25%) and excretion (40%), and greenhouse gases emissions (6%) by increasing individual nutrient efficiency in growing pig operations and it finally increased production, profit, and environmental conditions. In addition, Anonymous (2020) stated that locally, livestock production systems also contribute to preserving biodiversity and carbon sequestration in soils and biomass. In harsh environments, such as mountains and drylands, livestock is often the only way to sustainably convert natural resources into food, fiber, and work power for local communities.

IMPLEMENTATION OF PRECISION FEEDING IN FARM LIVESTOCK PRODUCTION

As the principle of precision feeding and its objectives to maximize as much as possible the efficiency of feed utilization by livestock, by supplying the most appropriate and precisely feeds and nutrients to the individual or group of livestock in a farm in real-time manner (Pomar et al., 2019), by involving all genetical and environmental factors that affect the utilization of feed and nutrients by livestock based on a real-time monitoring and incorporating all related sciences (including biology, physiology, microbiology, genetic, breeding, reproduction, chemistry, biochemistry, physic, math, health/medicine/immunology), technologies and equipment including tools to monitor genetic and environment factors, sensors, information and communication technology (ICT) in system construction and application of precision feeding, then implementation of precision feeding systems in commercial farms requires the integration of three types of activities: 1) automatic collection of data, 2) data processing according to the established control strategy, and 3) actions concerning control of the system (Pomar and Remus, 2019; Pomar et al., 2019). Thus, implementation of precision feeding must involve complex science and high technology that are appropriate mostly only in big commercial farms, but not in small farms where the majority of world farms or livestock are reared on this farm category. Thus, there must be a big variation of the implementation of precision feeding by farmers, starting from the very much simplest way of better feeding, e.g., selection of better-quality feed by smallholder farmers for their livestock to get higher livestock productivity until the actual precision feeding as described above by commercial farms to get as much as possible of advantages of precision feeding implementation.

CONCLUSIONS

Implementation of precision feeding is very promising for better, most productive, most efficient, and more sustainable livestock production. But there must be a considerable variation in its implementation rate and advantages due to the big variation of world livestock farms.

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The use of different levels of mulberry leaf meal with the broken-riceberry-based diet for semi-free range layers

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ABSTRACT

The present study investigated the effect of semi-free range laying hen fed dietary mulberry leaf meal mixed plus broken riceberry on egg performance, egg quality, and health. A randomized complete block experimental design was assigned, which block was a housing model (sunshine and shade). One hundred sixty laying hens (59 weeks of age) were divided into four groups in each house (20 birds of each group). The laying hens in each group were randomly assigned to 4 dietary treatments as follows: Diet 1, 2, 3, and 4, which were used broken riceberry as an energy source and mixed with 0, 2, 4, and 6 % sun-dried mulberry leaf meal, respectively. There were two consecutive 28 day periods to collect data based on egg production and egg quality. In the last period, the feces of each group were randomly collected to determine the number of microorganisms (total plate count, coliform, salmonella, and lactic acid bacteria). The results showed that there were no statistical differences among the four groups on egg production percentage, daily feed intakes, feed conversion ratio per 1 kilogram of egg weight, feed cost per 1 kilogram of egg weight, egg weight, albumen height, haugh unit, eggshell thickness, and the number of coliforms and lactic acid bacteria in feces ($P>0.05$). However, the egg yolk color scores were the highest, followed by diet 3, 2, and 1, respectively ($P<0.05$). The total plate count and salmonella in the feces of the laying hen fed with diet 4 were the lowest ($P<0.05$). In addition, feed cost per 1 kilogram of egg weight of the group fed with diet 4 was slightly lower than other groups.

Keywords: semi-free range layer, broken riceberry, mulberry leaf meal

INTRODUCTION

Nowadays, free-range laying hen (*Gallus gallus domesticus*) egg production is increasing within Thailand in response to consumer demand. Free-range chicken systems raise the chicken by letting them run freely or putting them together in a huge barn (floor pen egg); the chickens can move well and express any feelings. That is good for the animal's well-being or welfare, and then the eggs will be called "free-range eggs." Besides, feeding laying hens using locally sourced ingredients is another option for laying hens to produce free-range eggs and reduce the cost of animal feed. (Intralamongkol, 2010).

Riceberry or Jasberry Rice (*Oryza sativa*) is the healthiest rice that most farmers cultivate without chemical pesticides. It is a registered rice variety from Thailand, a Jao Hom Nin (JHN) crossbred, a local non-glutinous purple rice, and Khoa Dawk Mali 105 (Hom Mali rice). The variety was created by the Rice Science Center, Kasetsart University, Thailand, after four years of research for nutritional properties, anthocyanin stability, physical and cooking properties. The outcome is a deep purple whole grain rice with softness and a palatable aftertaste. (Agriculture Editor, 2014). Riceberry has been a popular brown rice substitute due to its health-promoting properties. Inducing people to consume more whole grain rice varieties could help ameliorate food-related chronic diseases like diabetes, heart disease, high blood cholesterol, obesity, and cancers (Sripaya, 2015). Riceberry is rich in nutritional value, with water-soluble mainly anthocyanin and lipid-soluble antioxidants, such as carotenoid, gamma oryzanol, and vitamin E. The nutritional properties of riceberry are concentrated in its bran, with only a small fraction in its endosperm. It is true of all cereals, meaning that it is best to consume whole rather than polished grains (Sirichokworrakit et al., 2015). In the polishing process of riceberry brown rice will have 10-15 percent of the broken riceberry. It is reported that broken riceberry can be used as an energy source in laying quail diets (Chalermsan et al., 2017). However, Chalermsan et al. (2017) reported that although the broken riceberry is dark in color, most of the colorants in the rice are dissolved in water, making them unable to accumulate in the yolk.

It may make the yolk pale than the corn. If a natural colorant found in locally grown plants is used as an ingredient in feed, it can increase the color of the yolk of the egg. Therefore, if broken riceberry are used together with mulberry leaf meal in laying hens, another natural source of locally grown protein and pesticide is not used. At the right level, it should be a way to produce new feed ingredients. That is both a source of energy, protein, colorants and health supplements for laying hens. It is consistent with organic livestock production for future farmers.

Mulberry leaf (*Morus alba*) may be an alternative source of dietary protein for poultry production. It is a tree fodder that grows well in the tropics and subtropics. Mulberry leaves are used for raising silkworms in the sericulture industry. Mulberry leaf meal is rich in protein (15-35%), minerals (Ca 2.42-4.71%; P 0.23-0.97%) and metabolizable energy (1,130-2,240 kcal/kg) with absence of or negligible anti-nutritional factors. Mulberry leaf contains carotene, which can be converted with varying efficiency by animals to vitamin A and xanthophylls, which may have potential in egg yolk pigmentation (Sarita et al., 2006).

The present study investigated the effect of semi-free range laying hen dietary mulberry leaf meal mixed with broken riceberry on egg performance, egg quality, and chicken health.

MATERIALS AND METHODS

This study was conducted at a poultry farm and the laboratory of the agricultural safety center, Rajamangala University of Technology Lanna, Phitsanulok Campus, Phitsanulok, Thailand. One hundred sixty ISA-Brown laying hens (59 weeks of age) were randomly assigned to dietary treatments using a randomized complete block experimental design. The dietary treatments were: Diet 1 (control group), 2, 3, and 4 used different levels of broken riceberry as main energy source and mixed with 0, 2, 4, and 6 percent of mulberry leaf meal, respectively. The treatment consisted of two blocks with 20 laying hens each. Broken riceberry was collected from brown rice milling that was grown without pesticides. Mulberry leaves were collected from the local area of Tumbol Bankrang, Mueang district, Phitsanulok province, and Buongsampan district, Phetchaboon province, Thailand. The leaves were initially cut into small pieces and then sun-dried for about 2-3 days. The sun-dried mulberry leaves were milled into a powder. The diets were formulated following the recommendation of the National Research Council (NRC, 1994) to satisfy the nutrients requirement of the laying hens. Diets consisted of 0 (control), 2, 4, and 6 % sun-dried mulberry leaf meal and were fed for two consecutive eight-week periods with free access for clean water consumption. Feed compositions and calculated nutrient content of experimental diets are present in Table 1.

Proximate analyses were carried out on the sun-dried mulberry leaf sample to determine: dry matter (DM), crude protein (CP), ether extract (EE), ash, crude fiber calcium (Ca), and phosphorus (P), using standardized procedures of the Association of Official Analytical Chemists (AOAC, 2000). Gross energy was analyzed by an AC500 Bomb calorimeter. The chemical composition (% DM) of mulberry leaves used in the present experiment is presented in Table 2.

During the experimental period, eggs production was collected and weighed daily. Data on feed intake were collected weekly. Egg production was recorded daily, but quality characteristics of eggs were determined every four weeks (one period). In the last three days of each period, four eggs of each group were collected for quality determination. Egg weight, albumen height, and haugh unit were analyzed by automatic Egg Quality Tester (Egg Multi – Tester model EMT-5200, Robotmation Co., Ltd., Japan). Yolk color score was measured by Roche yolk color fan, Switzerland. Eggshell thickness was measured by a digital eggshell thickness tester (Mitutoyo Co., Ltd., Japan).

Last week of this experiment, feces of each group was collected from the hens' vent after experimental feeding in the morning to determine microorganism count (total plate count, coliform, salmonella, and lactic acid bacteria). The method of determining microorganism count was described by Downes and Ito (2001).

Data were analyzed by analysis of variance (ANOVA). The significant differences between the treatment means were calculated by Duncan's Multiple Range Test. All analyses were performed by SAS Program (SAS, 1990).

Table 1. Feed compositions and calculated nutrient content of experimental diets of semi-free-range layers.

Feed ingredients (kg)	Diet 1	Diet 2	Diet 3	Diet 4
Broken riceberry	59.28	58.09	56.98	55.82
Rice bran	10.00	10.00	10.00	10.00
Soybean meal	15.45	14.68	13.88	13.10
Fish meal	5.00	5.00	5.00	5.00
Mulberry leaf meal	0.00	2.00	4.00	6.00
Oyster shell	8.60	8.50	8.38	8.27
Methionine	0.30	0.30	0.30	0.30
Palm oil	0.62	0.68	0.71	0.76
Salt	0.50	0.50	0.50	0.50
Premix	0.25	0.25	0.25	0.25
Total (kg.)	100.00	100.00	100.00	100.00
Calculated nutrient contents				
Crude protein (%)	16.00	16.00	16.00	16.00
Metabolizable energy (Kcal/kg)	2,900	2,900	2,900	2,900
Calcium (%)	3.75	3.75	3.75	3.75
Available Phosphorus (%)	0.36	0.36	0.36	0.35
Crude fiber (%)	3.61	3.64	3.67	3.70
Lysine (%)	1.41	1.44	1.47	1.50
Methionine + cystine (%)	0.51	0.51	0.51	0.51
Tryptophan (%)	0.18	0.18	0.18	0.18
Threonine (%)	0.51	0.51	0.50	0.50
Price (baht/kg)	14.11	13.92	13.72	13.53

RESULTS AND DISCUSSION

The chemical composition (%DM) of the mulberry leaf meal used in the present experiment is presented in Table 2. It showed that mulberry leaf meal contains 22.30 % protein, 4,180 Kcal/kg, 11.29 % crude fiber, 2.43 % calcium, and 0.62 % phosphorus. Similarly, Sarita et al. (2006) reported that Mulberry leaf meal is rich in protein (15-35%), minerals (Ca: 2.42 - 4.71%; P: 0.23- 0.97%). Besides, the report of Al-kirshi et al. (2010) showed that crude protein, crude fiber, Calcium, and phosphorus of mulberry leaf meal at four weeks of age were 29.80, 11.11, 2.73, and 0.28 %, respectively.

Table 2. Chemical compositions and gross energy of sun-dried mulberry leaf meal (%DM)

Chemical compositions	Mulberry leaf meal
Dry matter (%)	88.92
Crude protein (%)	22.30
Ether extracted (%)	5.12
Ash (%)	11.00
Crude fiber (%)	11.29
Nitrogen free extracted (%)	50.29
Calcium (%)	2.43
Phosphorus (%)	0.62
Gross energy (Kcal/kg)	4,128

Productive Performances

The result regarding productive performance is shown in Table 3. The egg production percentage (hen day and hen house production), daily feed intake, feed conversion ratio, feed cost per egg weight, and survival percentage did not differ significantly (P>0.05) among the layer groups fed the broken riceberry as energy source diets supplemented with different levels of mulberry leaf meal. The result indicated that providing a mulberry leaf meal up to 6 % in the laying hen diet had no detrimental effect on egg production performance. These results agree with the previous report of Kamruzzaman et al. (2012, 2014), who indicated that feeding of mulberry leaf meals up to 9 percent did not affect egg production, daily feed intake, egg weight, and feed conversion ratio. These results showed a reduction in feed intake with increased dietary mulberry leaf meals in the diets for laying hens. Hamdan et al. (2013) reported that the high fiber content in leaves reduced digestion and absorption of chickens, resulting in lower feed intake. Besides, a decrease in feed intake for increased levels of the mulberry leaf may be due to bulkiness and unpalatable taste, which may affect the hen's appetite. It is likely that using broken riceberry as the primary energy source, with mulberry leaves in the laying hen diet at 6 %, had the best feed conversion rate to 1 kilogram of eggs, and the cost of feed per 1 kilogram of egg production was lower than all groups. It may be because birds fed higher levels of the mulberry leaf meal in the diet were less fed, but the egg productivity did not decrease much.

Table 3. The effects of dietary treatments on egg production performance of semi-free-range layers.

Item	Mulberry leaf meal level in diets (%)				P-value
	0	2	4	6	
Hen-day production (%)	85.80 ± 1.64	86.01±6.14	82.77±3.15	84.73± 3.66	0.883
Hen-house production (%)	85.80 ± 1.64	86.01±6.14	82.68± 3.28	84.73± 3.66	0.877
Dairy feed intake (g/day)	118.21± 3.65	112.34± 1.39	114.77± 0.84	109.61± 7.87	0.446
Feed conversion ratio	2.38± 0.15	2.31± 0.23	2.45± 0.22	2.26± 0.07	0.804
Feed cost/egg weight (Baht/kg)	33.66± 2.11	32.23± 3.27	33.67± 2.98	30.56± 0.96	0.693
Survival percentage (%)	100 ± 0.00	100 ± 0.00	97.50± 3.53	100 ± 0.00	0.500

Egg Quality

The effects of dietary treatments on egg quality of semi-free-range layers are shown in Table 4. The results indicated that egg weight, albumen height, haugh unit, and eggshell thickness did not differ significantly (P>0.05) among the four groups. Likewise, Kamruzzaman et al. (2014) reported that the inclusion of mulberry leaf meal up to 9 % in the diet of laying hens had no effect on egg size, and the results are consistent with the Tateno et al. (1999). They found no significant difference in egg size after the hens were exposed to the diet's 15 % mulberry leaf meal. In contrast, Al-kirshi et al. (2010) reported the effects of inclusion of 0, 10%, 15%, and 20% of mulberry leaf meal in the diet on productive performance and egg quality of laying hens; they found that shell thickness and albumen weight did not affect (P>0.05), but haugh units increased as the level of mulberry leaf meal increased. However, laying hens fed broken riceberry as the primary source of energy at 2-6 % mulberry leaf meal were higher in yolk color score than that the control group (0 % mulberry leaf meal), especially the hens fed a diet with 6 % mulberry leaf meal had the highest yolk color score. It agreed with the results of Seeang (1997) and Al-kirshi et al. (2010) for the effects of mulberry leaf meal on egg yolk color score when mulberry leaf meal was given as part of the diet to laying hens. They found that feeding mulberry leaf meal improved the yolk color when compared with control (0 % mulberry leaf meal). Because mulberry leaves contain carotene that can be converted with varying efficiency by animals to vitamin A as well as a xanthophyll, these may have potential effects in the pigmentation of egg yolk (Sarita et al. 2006). Moller et al. (2000) reported that increases in egg yolk color are due to a more incredible content of carotenoids in egg yolk. The increase in egg yolk coloration indicated the high bio-availability of the xanthophyll in the leaf meals (Udedibie and Opara, 1998).

Table 4. The effects of dietary treatments on egg quality of semi-free-range layers.

Item	Mulberry leaf meal level in diets (%)				P-value
	0	2	4	6	
Egg weight (g)	59.33± 0.44	57.73± 0.96	58.43± 3.53	58.95±0.15	0.867
Albumen height (mm.)	6.95 ± 0.78	6.41 ± 0.29	7.44 ± 0.54	7.31 ± 0.95	0.394
Haugh unit	82.26 ± 5.01	79.17± 2.11	85.04± 1.35	85.51± 5.83	0.421
Yolk color score	2.00 ± 0.41[c]	3.11± 0.44[bc]	4.25±0.29[ab]	4.93±0.10[a]	0.015
Eggshell thickness (mm.)	0.47 ± 0.01	0.49± 0.01	0.47± 0.01	0.48± 0.01	0.550

[abc] Means with different superscripts within the same row are significantly different (P<0.05)

Microorganism Count in Feces

The effects of dietary treatments on microorganism count in feces of semi-free-range layers are in Table 5. The results showed that the total plate count and *salmonella spp*. in feces of the hens fed broken riceberry as the main source of energy, with 6 % mulberry leaf meal the lowest among four groups (P<0.05). The number of coliforms and lactic acid bacteria (beneficial microorganisms in the digestive tract) in the feces of 4 groups of birds were no different from each other (P>0.05). However, it is likely that the hens fed dietary increased levels (2-6 percent) of mulberry leaf meal, had a decrease in the number of coliform microorganisms in feces, and an increase in the number of lactic acid bacteria compared to the control group because the mulberry leaves are antibacterial substance. Antibacterial potential of the mulberry leaves extracted was screened against *Staphylococcus aureus, Pseudomonas aeruginosa, Streptococcus faecium, Escherichia coli, Neisseria gonorrheae and Proteus vulgaricus* etc. (Omidiran et al., 2012). In addition, Devi et al. (2013) reported that the leaf extracts of mulberry (Morus alba) were tested for antimicrobial activity against various bacterial strains and fungal strains compared to standard drugs. Results of the antimicrobial activity revealed that the extracts showed noticeable antimicrobial activity. Besides, in the study of Bharani et al. (2010), the extract of mulberry leaves has a significant effect on the humoral and cell-mediated immunity in experimental animals. Mulberry leaves contain biological active substances, including saponin, triterpenes (lupeol), sterols (β-Sitosterol), bioflavonoids (rutin, moracetin, quercetin-3-triglucoside and isoquercitrin), alkaloid and γ-aminobutyric acid (Srivastava, et al., 2006; Omidiran et al., 2012; Devi et al., 2013) as well as therapeutic activities. This particular has widely established and hidden therapeutic uses. The significant benefit of this medicinal plant is antidiabetic, immunomodulatory, antimicrobial, antioxidant and anticancer. (Devi et al., 2013)

Table 5. The effects of dietary treatments on microorganism counts in feces of semi-free-range layers. (log of cfu/g)

Item	Mulberry level in diets (%)				P-value
	0	**2**	**4**	**6**	
Total plate count	15.41±0.01[a]	15.17±0.02[ab]	14.84 ±0.05[b]	14.35±0.24[c]	0.008
Coliform	8.69 ±0.23	8.54±0.29	8.35±0.38	8.04+0.06	0.307
Salmonella	6.07±0.20[a]	5.10±0.10[b]	5.80±0.16[a]	4.50±0.31[c]	0.009
Lactic acid bacteria	11.75±0.39	12.22±0.05	12.32±0.16	12.17±0.05	0.164

[abc] Means with different superscripts within the same row are significantly different (P<0.05)

CONCLUSIONS

Based on the present study results, it can be concluded that the supplement of mulberry leaf meal is possible by up to 6 % in broken riceberry based-diets for semi-free-range layers without adverse effects on production and egg quality, but tended to improve the rate of conversion of feed, lower feed costs per 1 kg of egg, and improve pigmentation of egg yolk compared to the control. In addition, the diet that contained 6% mulberry leaf meal could have inhibited the growth of coliform and salmonella but enhanced the increase of lactic acid bacteria that is beneficial to animal health. Thus, feeding diets mixed with mulberry leaf meal with broken riceberry should be an alternative feeding regime to use local feed resources for safe egg production.

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Holstein steers grazing two Bermudagrass varieties in hot and dry summer: forage quality and physiological responses of steers

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ABSTRACT

The objective was to evaluate the forage quality of two varieties of Bermudagrass and some physiological traits of Holstein steers during two grazing periods in summer in an arid zone. Twenty-four Holstein steers (BW=200 ± 5 kg), 20 intact animals, and 4 with rumen cannulas were randomly assigned for grazing to the Bermudagrass varieties Cross 1 (BC1, n=12) and Giant (BG, n=12) in two consecutive periods (P1 and P2) during the summer-fall season in northwestern México. Based on the temperature-humidity index, the climate in P1 was considered as severe heat stress and P2 as moderate heat stress. Levels of CP and ash were higher ($P<0.05$) in BG during P2. Contents of NFD, AFD, and hemicellulose were higher ($P<0.01$) in BG during P2 than BC1 during P1, respectively. Only fat content was higher ($P<0.05$) in BC1 than BG. The *in vitro* digestibility of dry and organic matters showed no differences ($P>0.05$) between varieties or periods. Respiration frequency and all body surface temperatures were higher during the first grazing period and in the afternoon, which coincides with the hottest grazing period and time of day. In conclusion, climatic conditions of the site of the study along with a poor quality of Giant and Cross 1 Bermudagrass varieties under grazing conditions, make the nutritional supplement recommended to reach satisfactory results for growing cattle.

Keywords: *Bermudagrass*, *forage digestibility*, *grazing pastures*, *heat stress*, *Holstein steers*.

INTRODUCTION

The Mexicali Valley is located in the northwestern state of Baja California, and is one of the most important agricultural provinces of México. This valley is irrigated by water from the Colorado River that begins in the state of Colorado, USA. It flows to México in a controlled approach under an international agreement signed between the two countries. In this desert region of northwestern Mexico, beef cattle production is an important component of the livestock industry. It is economically one of the highest contributors to the agricultural segment of the region (Avendaño-Reyes et al., 2020). Around 90% of the meat from beef cattle production is produced in the Mexicali Valley, which provides around 80% of the total economic value of the livestock sub-segment in the state and has fourth place nationwide in beef meat production (SADER-Baja California, 2019). This livestock activity is based on feedlot operations, where calves from different breeds arrive after weaning from several Mexican states, such as Sonora, Chihuahua, Durango, Zacatecas, Jalisco, Veracruz, and Chiapas, among others. However, the recent increment in grain prices has led to grow the calves in irrigated pastures before they enter the corrals for intensive feeding in an attempt to reduce total production costs. In this arid region, summer weather is opposite to winter weather: summer months may reach 50°C, with temperatures above 30°C from May to October; meanwhile, winter temperatures can drop below 0 °C, with an average of about 15°C from November to February (García, 2004). This evident climatic scenario makes the crop establishment very differentiated. For grazing purposes, annual Ryegrass (*Lolium multiflorum L.*) is preferred during wintertime, with excellent results for the growth of cattle (Mejía-Delgadillo et al., 2011). However, during summer, there is no pasture defined, even though some irrigated pastures have been proven with poorer results compared to winter grasses (Vargas and Yáñez, 1996). The use of Bermudagrass for grazing cattle represents a valuable forage resource due to its acceptable nutritional value, rapid regrowth for grazing, great tolerance to extreme climatic conditions, and slight resistance to drought (Hacker and Jank, 1998). The Bermudagrass varieties Giant and Cross 1 are characterized by their resistance to grazing, medium quality forage, and good palatability during grazing; however, the limitation of nutritional values includes low protein crude and energy content, as well as high fiber level (Galloway et al., 1993). One option for the Mexicali Valley can be the establishment of Bermudagrass for growing cattle during summer for a period of 180 - 210 d, depending on the ambient temperatures for growth and rapid regrowth (Scaglia and Boland, 2014). The condition of extreme heat stress occurring during summer is a factor that may affect calves during grazing, increasing animal´s body temperature and reducing their grazing ability. Heat stress can be generated as part of a combination of ambient temperature, relative humidity, and is reflected in a high temperature-humidity index (THI; Hahn et al., 2003). Also, the increase in the fibrous fraction of the grass as the plant grows generates an increase in metabolic heat that raises body temperature and reduces weight gain in cattle (Gebremedhin et al., 2016). There is a lack of scientific information about the influence of grazing periods and varieties of Bermudagrass on physiological and digestive variables. Therefore, the objective of this study was to evaluate the effect of two grazing periods during the summer-fall season on forage quality parameters and physiological variables of Holstein steers grazing two varieties of Bermudagrass in an arid region.

MATERIALS AND METHODS

All procedures involving steers were performed following the guidelines of approved Mexican Official Standards (NOM – 051 – ZOO - 1995: Humanitarian care of domestic and wild animals).

Study Location

The study was carried out in the Experimental Beef Cattle Unit of the Instituto de Ciencias Agrícolas, which belongs to the Universidad Autónoma de Baja California, located in the Ejido Nuevo León, Mexicali Valley, Baja California, México (32° 24´ N and 115° 11´ W). The climate of this arid region is hot and dry, with an average annual temperature of 22°C, being January the coldest and July the hottest month, with averages for maximum and minimum temperatures of 13 and 1.66°C, and 45 and 20 °C, respectively (INEGI, 2010).

Animals and Treatments

Two plots of 1.5 ha, each already established with two varieties of Bermudagrass: Cross 1 (BC1) and Giant (BG), were used. After each grazing, paddocks were fertilized with N (70 kg N/ ha^{-1}) before irrigation of the pasture. Twenty-four Holstein steers and four cannulated with an average live weight of 200 ± 5 kg were randomly divided into two groups of 10 intact animals and 2 with rumen and duodenal cannulas, one for each Bermudagrass variety. Animals were treated with vitamins (A-D-E; 4 mL/steer of Vigantol, Bayer Laboratory, México) and against parasites (6 mL/steer of Ivermectina, Sanfer Laboratory, México). Previous to initiating the study, an adaptation period of 30 d was given to the steers. So two varieties, BC1 and BG, and two periods of 75-d during summer-autumn (June 3rd to October 31st) were evaluated. Periods were characterized by the intensity of heat stress: the first period (P1) covered the first 75 d, while the second period (P2), the next 75 d. Steers had free access to a shaded pen and to the pasture; pens provided with waterers, and there was no supplement offered to the steers.

Forage Sampling

Two cannulated steers per treatment were used for the collection of forage samples with the following schedule: day 1, 09:00, and 21:00 h; day 2, 13:00 and 01:00 h; day 3, 17:00 and 05:00 h. The procedure to take the aliquot of forage consisted of identifying by visual observation the nearest site the animal was grazing, considering similar structure to the animal at the scheduled time defined; from the observed spot, a cut with garden shears was obtained of ~ 50 g of fodder at a similar height to which the animal had grazed. The samples were placed in paper bags and weighed on a digital scale. They were finally dried at 55 ºC for 72 h in a forced-air oven and ground in Willey® mill using 2 mm mesh. Samples of the different days and times per animal and period were combined to take an aliquot of ~ 70 g. This was preserved in a plastic container with airtight closure for later analysis (Laca et al., 1989).

Forage Chemical Composition and Nutritional Value

In the selected forage samples and using the Near-Infrared Spectroscopy (NIRS) method, the following standard determinations of nutritional value were estimated: dry matter (DM), crude protein (CP), ash, fat, neutral detergent fiber (NDF), acid detergent fiber (ADF). The NIR System model 6500 (Foss-NIRSystems Silver Spring, MD, USA) was used for the spectra readings, which included a reflectance detector and a sample rotation module. The equipment was managed using the WinISI 1.04 software38 (ISI Windows Near-Infrared Software, WinISI II, version 1.02A, Foss NIRSystems, Silver Spring, MD, USA) for both processes optical data and to develop calibrations. The absorbance values ([log (1/R)] were kept as the average of the three subsamples. Hemicellulose (HM) was determined according to the method established by Goering and Van Soest (1970) and the digestive variables in vitro digestibility of organic matter (IVDMO) and in vitro digestibility of dry matter (IVODM) according to the method established by Tilley and Terry (1963).

Climatic Variables

The climatic data were obtained from a weather station located in the study site and consisted of hourly registration of ambient temperature (AT) and relative humidity (RH). With this climatic information, the THI was calculated using the following formula proposed by Hahn (1999):

$$THI = 0.81\ AT + RH\ (AT - 14.4) + 46.4$$

Where:

THI = Temperature-Humidity Index (Units),
AT = Ambient Temperature (ºC), and
RH = Relative Humidity (%).

Physiological Variables

Two different physiological variables were recorded in the present study: respiratory frequency (RF) and body surface temperatures (BST). The respiratory frequency was recorded through visual observations by counting the flank movements using a manual counter and a stopwatch for 60 seconds. The body surface temperatures were recorded from the anatomical regions: nose, eye, head, rump, loin, belly, and paddle in 5 steers on each Bermudagrass variety. They were measured during the first three weeks of each sampling, two days (Wednesday and Friday) per week at three different times (07:00 [AM], 13:00 [AFT], and 19:00 [PM] h). A digital infrared thermographic camera (Fluke Ti100, Everett, WA, USA) taking photos at 1.0 - 1.5 m distance from the steers was used. Subsequently, pictures were downloaded to a computer to be collected with the Fluke SmartView® software.

Statistical Analyses

The physiological variables RR and BST were analyzed with a 2x2x3 factorial arrangement under a completely randomized design with repeated measurements over time, where the factors were Bermudagrass varieties (VAR: BC1 and BG), grazing periods (PER: P1 and P2), and time (TIME: AM, AFT, PM). Adjusted means were obtained using the command PDIFF of the PROC MIXED from SAS (SAS, Institute. Inc., Cary, NC) version 9.2. Several covariance structures were tested, and the first-order autoregressive showed the best fit according to the AIC and BIC criteria (Littell et al., 1996). The digestive variables (IVDOM and IVDDM) were analyzed with a 2x2 factorial arrangement under a completely randomized design, considering the variety and period of the factors. The factorial effect averages were estimated using the LSMEANS procedure and the comparison between them by the command PDIFF STDERR. A significance between means was considered only at 0.05 level, using the GLM procedure of the SAS statistical program (SAS Institute Inc., Cary, NC) version 9.2. However, the trend was considered with a probability greater than 0.05 but less than 0.10.

RESULTS AND DISCUSSION

Climatic Variables

The prevailing climatic data during the study period are presented in Table 1. As expected, averages of TA, RH and THI were higher in P1 than in P2. It is observed that in P1, extreme weather conditions were recorded and are typical of a desert region, consequently critical for beef production. The average RH fluctuated between 38.2 and 56.1%, with a general average of 49%, values considered distinctive of desert areas. The overall average of the THI during the study was 76.8 units, with a range of 82.6 and 68.5 units in the months of July and October, respectively. On the other hand, it can be noted that during September and October (P2), the THI decreased even below 70 units (75.2 and 68.5 units, respectively).

Forage Quality Parameters

Results of the analysis of variance for the chemical composition and digestibility parameters used in this study are shown in Table 2. The interaction VAR x PER was significant ($P<0.05$) for the variables CP and ash, while NFD, AFD, and HM were affected independently by both main effects VAR and PER. Fat differed ($P<0.05$) by VAR, and digestibility parameters (IVDDM and IVDOM) showed just a trend ($P<0.10$) to be affected by PER. Percentages of NFD, AFD, and HM were higher ($P<0.01$) in BG than in BC1 (56.1 vs. 45.8%, 34.5 vs. 26.9%, and 21.6 vs. 19.0%, respectively), while fat percentage was higher ($P<0.01$) in BC1 than in BG (2.22 vs. 1.77%). There was a trend ($P<0.10$) for NFD, AFD, and HM, observing higher values during P2 compared to P1 (52.6 vs. 49.4%, 31.9 vs. 29.5%, and 20.8 vs. 19.8%, respectively).

Table 1. Descriptive statistics of climatic variables by month and period during the study.

	Ambient temperature (°C)				Relative Humidity (%)				THI (Units)			
	Min	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
Months												
June	20.1	39.2	29.8	7.4	17.3	83.1	46.8	26.5	66.3	82.9	76.3	6.9
July	26.2	40.3	33.1	5.2	26.2	89.0	56.1	23.2	77.4	88.7	82.6	3.6
August	25.1	41.1	33.2	5.7	22.2	83.5	49.6	23.8	75.1	88.2	81.2	4.9
September	20.0	35.1	27.5	6.4	29.4	81.3	54.4	28.9	67.6	81.3	75.2	7.6
October	15.1	33.5	24.1	6.7	16.7	65.8	38.2	23.2	58.8	76.9	68.5	6.7
Periods												
Period 1	23.8	40.2	32.0	6.1	21.9	85.2	50.8	24.5	72.9	86.6	80.0	5.1
Period 2	20.1	36.6	28.3	6.3	22.8	76.9	47.4	25.3	67.2	82.1	75.0	6.4

THI: Temperature-Humidity Index, Min: Minimum, Max: Maximum, SD: Standard deviation.

Table 2. Effects of Bermudagrass varieties (BC1 and BG) and grazing period (P1 and P2) and their interaction on the nutritional value and in vitro digestibility of the forage during the study.

	VARIETY				PERIOD				Interaction
Items, (% DM)	BC1	BG	SEM	*P-value*	P1	P2	SEM	*P-value*	VAR*PER
CP	4.28	6.46	0.53	0.02	4.13	6.61	0.53	0.01	**<0.01**
Fat	2.22	1.77	0.09	<0.01	2.00	2.00	0.09	1.00	0.78
Ash	3.66	6.10	0.32	<0.01	4.19	5.58	0.32	0.01	**0.01**
NFD	45.8	56.1	0.92	<0.01	49.4	52.6	0.92	0.04	0.06
AFD	26.9	34.5	0.70	<0.01	29.5	31.9	0.70	0.04	0.08
Hemicellulose	19.0	21.6	0.22	<0.01	19.8	20.8	0.22	0.03	0.06
Digestibility, (%) IVDDM	45.2	48.5	1.68	0.20	44.4	49.3	1.68	0.08	0.39
IVDOM	51.8	54.4	1.59	0.28	50.8	55.5	1.59	0.07	0.44

BC1: Bermuda Cross 1; BG: Giant Bermuda; P1: Period 1; P2: Period 2; CP: Crude protein; NFD: Neutral detergent fiber; AFD: Acid detergent fiber; IVDMD: *In vitro* digestibility of dry matter; IVDOM: *In vitro* digestibility of organic matter

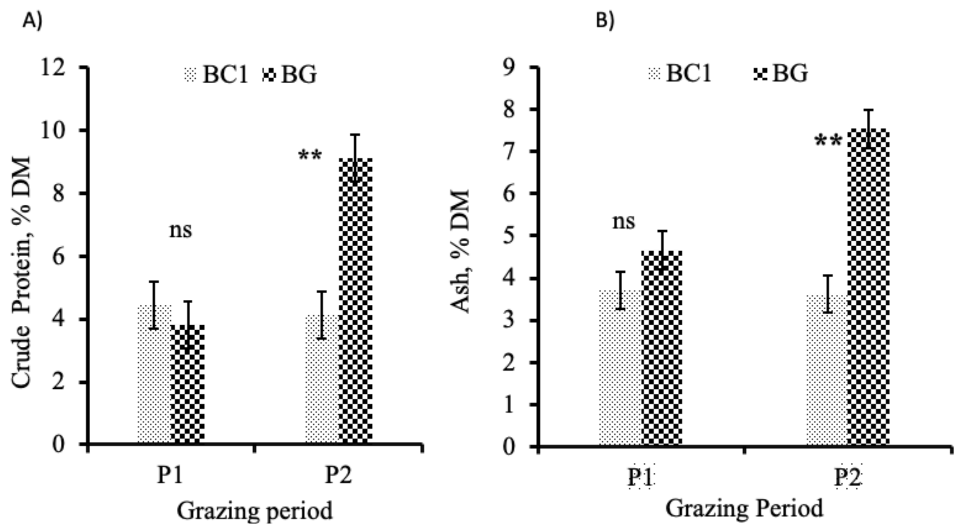

Figure 1. Averages (mean±SEM) of A) crude protein and B) ash for the interaction grazing period * variety during the study (ns: P>0.05; **: P< 0.01). These show the interaction VAR x PER for CP and ash. In P1, BC1 had higher (P<0.01) CP content than BG (4.44 vs. 3.81 %); however, in P2, BG had higher (P<0.01) CP content than BG (9.11 vs. 4.11%). Ash was higher (P<0.01) for BG than BC1 in both P1 (4.66 vs. 3.71%) and P2 (7.54 vs. 3.62%). Finally, the IVDDM and IVDOM tended to be higher (P<0.10) in 10 and 8.5% during P2 compared to P1

Physiological Variables

The influence of Bermudagrass varieties, grazing periods, and time, as well as their interactions on physiological variables of Holstein steers, are presented in Table 3. The interaction VAR x PER x TIME was not significant for any physiological variable. However, RF, and temperatures of rump, paddle, and belly were affected (P<0.05) by VAR x PER and PER x TIME interactions. Meanwhile, temperatures of head, loin, nose and eye were affected (P<0.05) just by PER x TIME interaction. So results of these variables will be explained in terms of interactions (figures) and main effects (tables). Finally, eye temperature was affected (P<0.05) by the Bermudagrass variety.

Figure 2 shows the interactions VAR x PER and PER x TIME for the variable RF. During P1, steers grazing BG exhibit higher (P<0.05) RF than steers grazing BC1 (65 vs. 60 bpm); however, during P2 both groups of steers had similar (P>0.05) RF (~ 45 bpm). On the other hand, RF was higher (P<0.05) at AFT (80 bpm) than PM (58 bpm) and AM (48 bpm) hours during P1; a similar pattern was observed during P2 but with smaller values. Figure 3 shows the interactions VAR x PER and PER x TIME for the variable rump temperature (TRump). Steers grazing BC1 and BG reduced (P<0.05) their TRump from P1 to P2 in 4.8 and 5.8°C; however, TRump of steers grazing both varieties of Bermuda within periods was essentially similar (P>0.05). Daily average TRump at AFT was the highest (P<0.05), followed by TRump at PM; during the morning, TRump reached the lowest (P<0.05) temperature. This scenario was similar for P1 and P2. Figure 4 shows the interactions VAR x PER and PER x TIME for the variable belly temperature (TBelly). Steers grazing BC1 and BG reduced (P<0.05) their TBelly from P1 to P2 in 4.6 and 5.5°C; however, steers grazing both varieties of Bermuda within periods were essentially similar (P>0.05) in TBelly. Figure 5 shows the interactions VAR x PER and PER x TIME for the variable paddle temperature (TPaddle). Steers grazing BC1 and BG reduced (P<0.05) their TPaddle from P1 to P2 in 5.3 and 6.9°C; however, TPaddle of steers grazing both varieties of Bermuda within each period was essentially similar (P>0.05). The results from the interaction PER x TIME for the physiological variables THead, TLoin, TEye, and TNose showed the same pattern as TRump (Figure 6), reaching the highest temperature in the afternoon. Lastly, steers grazing BG exhibited higher (P<0.05) TEye than steers grazing BC1 (Table 3).

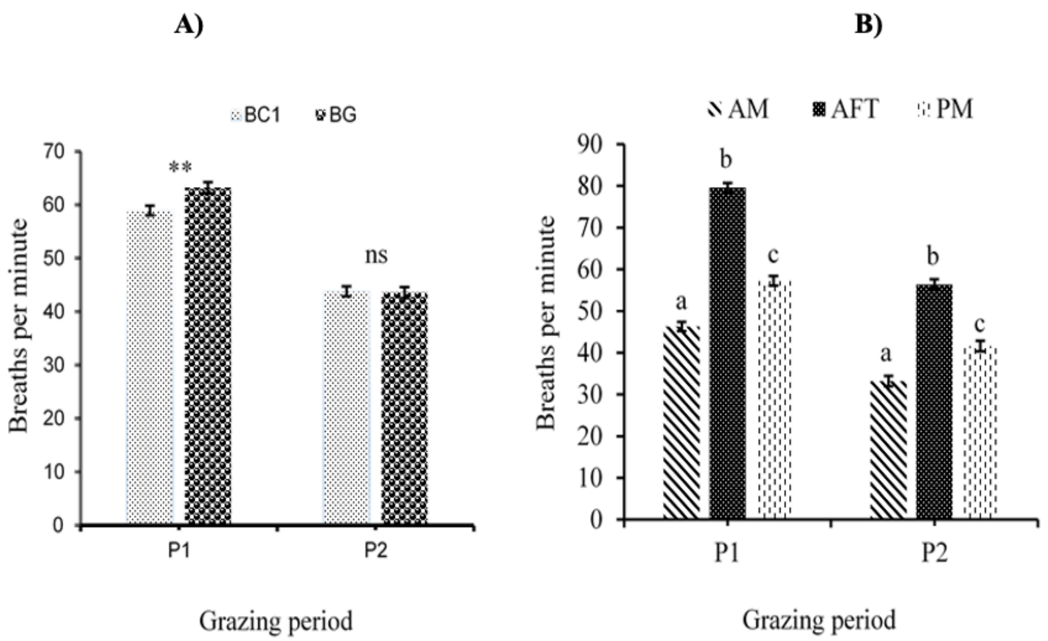

Figure 2. Averages (mean±SEM) of respiration frequency (RF) of Holstein steers for the interactions A) grazing period * variety and B) grazing period * time of day during the study (ns: P>0.05; *: P< 0.05; ** P< 0.01). [abc]Means of time of day within grazing period with different superscript differ (P< 0.05).

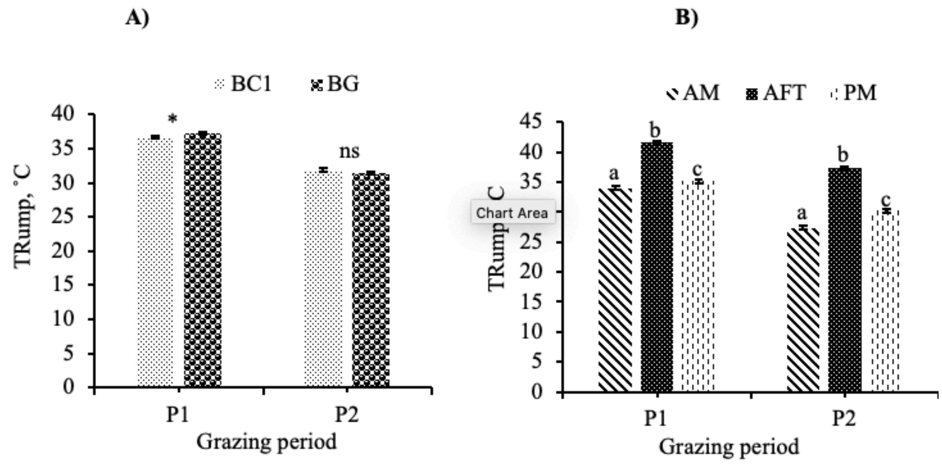

Figure 3. Averages of rump temperature (TRump) of Holstein steers for the interactions A) grazing period * variety and B) grazing period * time of day during the study (ns: P>0.05; *: P< 0.05). [abc]Means of time of day within grazing period with different superscript differ (P< 0.05).

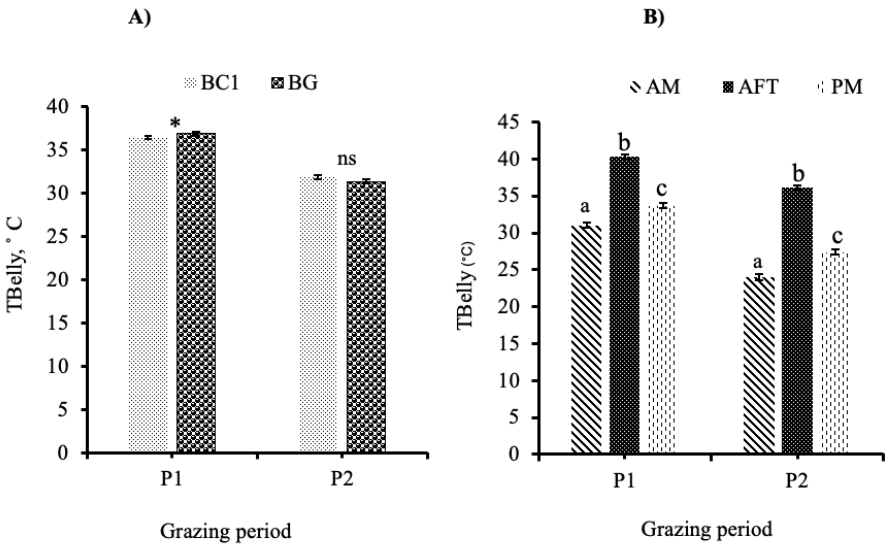

Figure 4. Averages of belly temperature (TBelly) of Holstein steers for the interactions A) grazing period * variety and B) grazing period * time of day during the study (ns: P>0.05; *: P< 0.05). [abc]Means of time of day within grazing period with different superscript differ (P< 0.05).

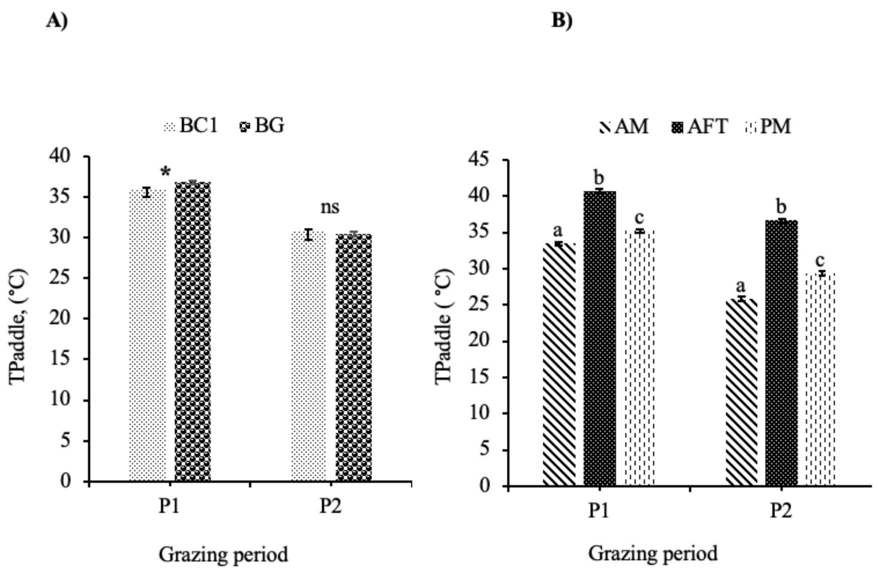

Figure 5. Averages of paddle temperature (TPaddle) of Holstein steers for the interactions A) grazing period * variety and B) grazing period * time of day during the study (ns: P>0.05; P< 0.05;). [abc]Means of time of day within grazing period with different superscript differ (P< 0.05).

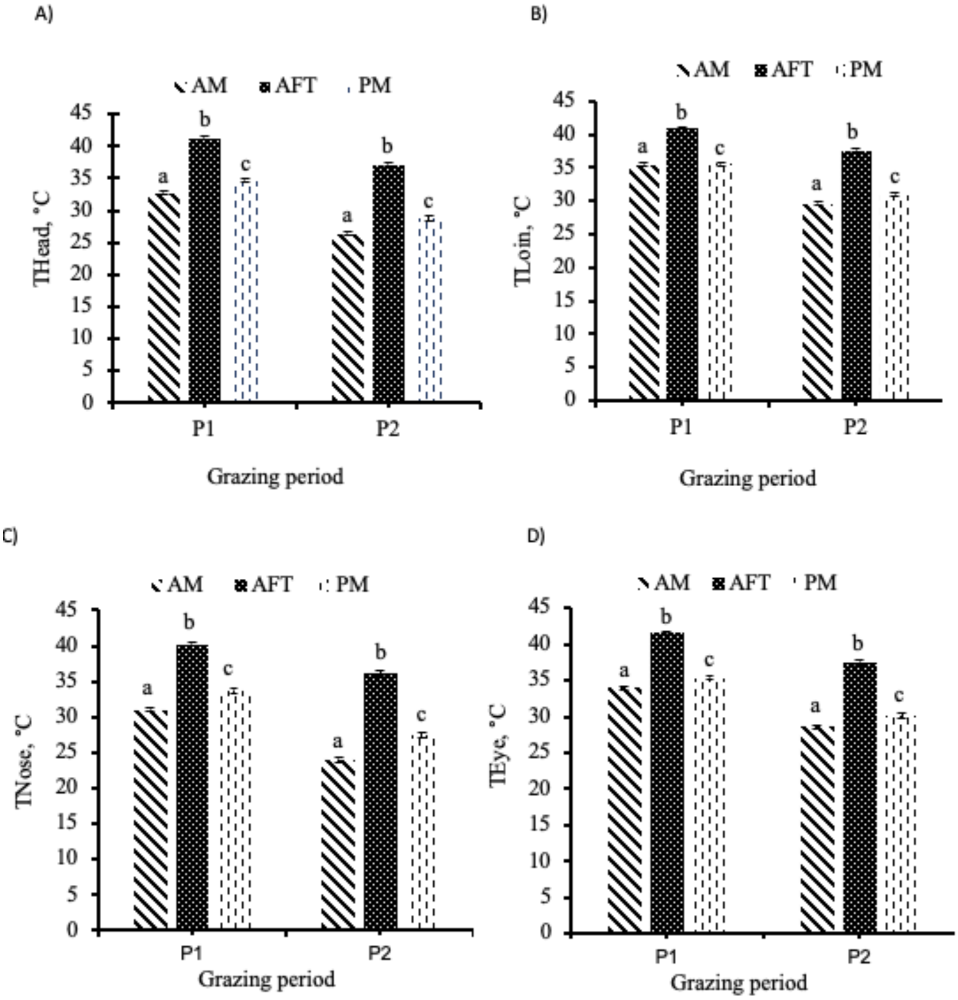

Figure 6. Averages of A) head temperature (THead), B) loin temperature (TLoin), C) nose temperature (TNose), D) eye temperature (TEye) of Holstein steers for the interactions grazing period * time of day during the study. [abc]Means of time of day within grazing period with different superscript differ (P< 0.05).

Table 3. Effects of the bermudagrass varieties (BC1 and BG), grazing periods (P1 and P2), times of day (AM, AFT, and PM), and their interactions on physiological variables (respiration frequency and body surface temperature) of Holstein steers.

	Varieties				Periods				Times of day					Interactions			
Item	BC1	BG	SEM	P-value	P1	P2	SEM	P-value	AM	AFT	PM	SEM	P-value	V*P	V*T	P*T	V*P*T
RF, (bpm)	51.2	53.5	0.70	0.02	61.0	43.7	0.71	<0.01	39.5	68.3	49.3	0.86	<0.01	0.02	0.23	<0.01	0.49
Thead (˚C)	33.4	33.6	0.16	0.30	36.2	30.8	0.16	<0.01	29.6	39.1	31.8	0.19	<0.01	0.30	0.18	<0.01	0.86
TLoin (˚C)	35.1	34.9	0.15	0.28	37.3	32.7	0.15	<0.01	32.6	39.2	33.2	0.18	<0.01	0.10	0.45	<0.01	0.32
TRump (˚C)	34.2	34.3	0.16	0.61	36.9	31.6	0.16	<0.01	30.8	39.4	32.7	0.20	<0.01	0.02	0.91	<0.01	0.64
TNose (˚C)	32.0	32.1	0.21	0.76	35.0	29.1	0.21	<0.01	27.6	38.1	30.6	0.26	<0.01	0.72	0.62	<0.01	0.90
TEye (˚C)	34.3	34.7	0.16	0.05	36.9	32.0	0.16	<0.01	31.3	39.5	32.7	0.20	<0.01	0.15	0.13	0.03	0.67
TPaddle (˚C)	33.4	33.7	0.16	0.21	36.5	30.6	0.16	<0.01	29.8	38.6	32.2	0.20	<0.01	0.02	0.16	<0.01	0.50
TBelly (˚C)	34.1	34.1	0.16	0.87	36.6	31.6	0.16	<0.01	30.8	38.8	32.8	0.19	<0.01	0.05	0.59	<0.01	0.66

bpm: breaths/min; BC1: Bermuda Cross 1; BG: Giant Bermuda; P1: Period 1; P2: Period 2; AM: Morning; AFT: Afternoon; PM:Night; V*P:VAR*PER; V*T: VAR*TIME; P*T: PER*TIME; V*P*T:VAR*PER*TIME; T:Temperature

Climatic Variables

According to Ravagnolo et al. (2000), a THI greater than 72 units is the threshold where dairy cattle start to exhibit symptoms of heat stress. Moreover, Berman (2006) and Mader et al. (2002) consider that a THI ≥ 74 is an indicator that beef animals make physiological adjustments to prevent a rise in their body temperature due to hot environmental conditions. In the present study, the average THI from June to September was higher than 74 units, which is the threshold for heat stress in beef cattle. Only the month of October showed a THI lower than 74 units. However, when the THI was estimated by period, P1 and P2 were in average 80 and 75 units, respectively. The intensity of heat stress in the first period is classified as severe heat stress, while the second period is classified as mild heat stress. In average, both periods were classified as heat stress for grazing cattle. Temperature alone is not considered a good method to measure heat stress in domestic animals, and this is because heat stress is also associated with relative humidity. However, in arid zones, humidity is not as high as in tropical ecosystems but should be considered (Hahn et al., 2003). The Mexicali Valley is an arid zone with temperatures during the hottest months of summer that can reach 50°C, which occurs in July and August; after these months, ambient temperature decreases so that September was the month with the lowest ambient temperature during the study.

Forage Quality Parameters

Bermudagrass is a C4 grass well adapted to the transition warm-arid ecological system since their exposure to high environmental temperatures results in changes in physiological, metabolic, and biochemical processes. These changes provided them the ability to attain thermotolerance to prolonged heat stress episodes (Kumar et al., 2013). Acquisition of high-quality forages for grazing purposes helps to reduce purchases of additional feedstuffs for cattle during summer months; however, in general quality of Bermudagrass during this season is considered low. Our results showed that protein, fat, and ash levels agree with this statement; nevertheless, BG exhibited better quality than BC1 in both grazing periods during summer. However, all the composition values observed in the two Bermudagrass varieties studied here were lower than those reported by other authors in different latitudes such as Jones et al. (1988), Galloway et al. (1993), Wheeler et al. (2002), and Juárez-Reyes et al. (2009). It is important to mention that a CP content of at least 8% is considered the beginning for microbial growth in the rumen and to provide amino acids to the animal´s body (Kearl, 1982; Stern and Hoover, 1979). In our particular case, this nutritional requirement was not covered by any Bermudagrass variety. Despite forage quality slightly improved when environmental conditions were less drastic, which is from P1 to P2, minimum thresholds were not reached. Gutiérrez (2013), in the same experimental site, reported similar differences in the chemical composition for BC1 between subsequent periods (1 and 2) during summer. The fiber content of grass is determined by the content of NDF percentage, which varies in grass grazed from 30% in fresh spring grasses to 50% in stem grasses. In the present study, BG exceeded this threshold of NDF, reaching 56%, which was 10.3% higher than NDF content of BC1. Grasses with high fiber content are associated with a restriction of voluntary feed intake, reduction of body condition, and production losses (Minson, 1990). Also, the body heat increment (given by the higher RF and TEye) was associated with high fiber levels in steers consuming Giant Bermudagrass.

Even though digestibility results were not significant, they indicate a trend towards increasing as the weather changed from severe to mild HS conditions. The results of IVDOM by period agree with those obtained in the study carried out by Gutiérrez (2013), who found an increase in IVDOM of BC1 from the first to the last grazing period, using 3 grazing periods during his study. The observed values of IVDDM in both varieties were lower than those reported by Cabanillas et al. (2017) in pastures BC1, Cross 2, and Santo Domingo, which is attributed to the fact that the varieties used in the present study had lower CP levels. Mathews et al. (1994) estimated the average of IVDOM in Holstein heifers grazing Bermudagrass in a tropical region, and they found similar values of IVDOM to those reported in the present study.

Physiological Variables

Studies in cattle under heat stress report that when the respiratory frequency ranges between 20 and 60 breaths per minute, animals are in thermoneutral conditions, but when it increases from 80 to 120 breaths per minute, they are considering moderate to severe heat stress (Gaughan et al., 1999; Lees et al., 2019); this effect was observed in the present study. A similar result in grazing cattle during summer was reported by Brown-Brandl et al. (2003), with an ambient temperature of 18, 30, and 34 oC, the RF raised from 56 to 84 and then to 103 breaths per minute, respectively.

In the present study, the higher RF was observed when the ambient temperature rises afternoon (13:00 h) and during P1, compared with 07:00h and 17:00 hours and P2; this coincides with Echeverri-Echeverri et al. (2018), who used Holstein steers for grazing during summer at 31.4 °C of ambient temperature, where the respiratory frequency was greater than autumn at 30.4 ° C (80 vs 56 breaths per minute, respectively). In the same way, O'Brien et al. (2010) observed an increase in RF of heifers of 135 kg of live weight at TR of 29.4 and 40.0 °C from 80 to 117 breaths per minute at 07:00 h and 18:00 hours, respectively. Yadav et al. (2017) exposed crossbred cattle to 25, 35, and 40°C for 5 h/d during 21 d in a climatic chamber, finding that rectal temperature, respiration rate, and pulse rate increased linearly as temperature increased.

In general, BST followed a circadian rhythm of cattle during summer: the lowest BST was during the morning, then the maximum BST was obtained in the afternoon and reduced again during the nighttime. Also, differences between periods were observed, which was totally attributed to the climatic conditions. For instance, when the measurements were considered in the afternoon in P1, the belly temperature of the steers grazing BG was 40.8 ° C, while at the same time, during P2 was only 37 °C. Echeverri-Echeverri et al. (2018) reported higher loin than rump temperature, which was attributed to the fact that this anatomical region is located near the rumen so that effects of animal physiology are combined with the metabolic heat produced to increase body temperature.

In a study conducted by Anzures-Olvera et al. (2015) using Holstein multiparous lactating cows under confinement and heat stress conditions, temperature of head was lower than those reported in the present study. The fact that steers had a shaded pen for resting and that grazing was with no restriction may account for avoiding high solar loads to find a comfortable site for protection. Yadav et al. (2019) exposed crossbred cattle to 25 and 40°C for 21 days in a climatic chamber to assess their acclimatization to heat stress. They found that cattle needed a period of 6 to 21 days for acclimatization to extreme temperatures since factors such as biochemical, physiological, and endocrine processes are involved.

The BST registered at different anatomical sites in ruminants can be used as a signal of stress and precision farming under different production systems (Poikalainen et al., 2012). The disparity in BST at several locations indicated that the temperature of skin surface not only varied with changes in ambient temperature but also varied in some anatomical regions of the body at a specific time of the day and grazing period (Roberto and De Souza, 2014). In this study, temperatures of paddle, eye, and loin at 13:00 h were the highest; meanwhile, nose and paddle registered the lowest surface temperatures during P1. So rump and loin were anatomical regions where grazing steers experimented with more heat loss activity. This heat interchange is because when animals are grazing outdoors, paddle, loin, and head are subjected to intense heat loads from the environment (Yadav et al., 2017). Evaluating the BST of Hanwoo, a Korean *Bos taurus* breed, Kim et al. (2014) reported temperatures of eyes (37.9, 42.2, and 39.6 °C) and ears (36.8, 41.8, and 38.5 °C) during summer at 07:00, 13:00, and 19:00 h respectively; these surface temperatures followed the circadian pattern of the THI which was 76, 85.6 and 78.7 units in the same order of time of day. They concluded that the eye showed the temperature more stable, reflecting effectively the temperature surrounding animals. Even though our steers had access to a shaded pen and to water *ad libitum* in the corral, the high ambient temperatures avoid them to maintain body temperatures under normal conditions (~ 39°C). In general, the physiological responses were affected by heat stress conditions as a consequence of the ITH observed in the first period and the higher NDF content of the Giant Bermuda grass.

CONCLUSIONS

Bermudagrass Giant variety showed better nutrient quality than Cross 1 based on protein and ash content, but *in vitro* digestibility of organic and dry matter was similar between these two varieties established under hot and dry climatic conditions of the arid zone studied. Holstein steers had more signs of heat stress during the first grazing period than the second one because THI was more intense. Body surface temperatures of loin and rump presented higher temperatures taken with infrared thermography. Use of Bermudagrass varieties Giant or Cross 1 for grazing purposes under extremely arid conditions should be accompanied by a feed supplement since the nutritional quality of those forages is considered medium-low.

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