THE STUDY OF MANUFACTURING EDIBLE BEEF SKIN

By

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THE STUDY OF MANUFACTURING EDIBLE BEEF SKIN

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Abstract: The purpose of this study is to manufacture edible beef skin (Ponmo). Getting off hair from the hide is a major issue in the manufacturing process. Different treatments like mechanical, Skinned, Trimmed, and Chemical dehairing were performed on beef hides, followed by scorching with heated steel plates. Quality attributes like Color (CIE L*, a*, b*), Texture (Texturometer), Moisture were analyzed. A Hedonic scale expert sensory (1 to 9) was conducted to investigate the color and texture of developed treatments. A high moisture level was observed in mechanical and chemical dehairing treatments. A significant difference in hardness existed between all the treatments ($P < 0.05$). The chemical treated samples were more preferred by the expert sensory panel for color and texture when compared with other treatments. Long scorching time and temperature were observed for mechanical treatment. No significant relationship existed between the Hedonic scale and CIE L*, a*, b*.

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CHAPTER I

INTRODUCTION

In the meat processing industry, much of the waste has been produced in slaughter facilities. In the United States meat industries, everything produced from the animal, except the dressed carcass, is considered a byproduct. Byproducts are divided into edible offal (which includes a variety of meats) and non-edible offal (includes hides and skins, fats, blood and blood tissues, horns, teeth, bones, and lungs). Edible and non-edible offal adds up to 44% of cattle's live weight, and 30% of hogs' live weight. Byproducts from the slaughter facilities have a prominent place in the pharmaceutical, cosmetic, and leather industries (Daniel L. Martie et al., 2011).

Skins of animals such as cows, goats, and sheep are utilized as a raw material in the manufacturing of leather goods, including shoes, bags, and belts. Like India, West Africa, and the United States, animal skins are considered edible in many parts of the world when further processed. In the United States, pork rind is a popular snack food manufactured from pork skins. In Jamaica, cow skin is traditionally used in soups and stews. It is reported that cow skin soup is used to cure a hangover in Jamaica. In West Africa, cow skin is used in soups and stews. The cow skin soup in West Africa is called Sopa Canja.

Foods from processed cattle hides are extremely popular in South-Western Nigeria and southern Ghana. They are called 'Ponmo', 'Welle', and 'Kanda' in Nigeria. The hair is traditionally removed from the hide by tenderizing the rawhide in hot water and then scraping by using sharp knives or razor blades (Okafor et al., 2012). There are two types of ponmo, the finished product due to dehairing the hide by shaving is called white ponmo, and the finished product due to dehairing by singeing is called brown ponmo (Dada et al., 2018). Different processors have introduced unique ways of manufacturing ponmo in the past few 10decades. Methods include the singeing of hair using different fuels such as firewood, engine oil, plastic, and used tires. The singed skins are scraped to take out the ash, followed by boiling in water. These methods have been reported to leave residues of toxic substances that contaminate hides, making them unsuitable for human consumption (Okiei et al., 2009).

Hides processed using firewood and spent engine oil may contain polyaromatic hydrocarbon dioxins and benzene (Okiei et al., 2009). Lead, a toxic metal present in some engine oil, can contaminate the hides. Wood-burning may lead to residuals of dioxins which promote skin disease (US EPA, 1994). Burning polystyrene polymers (plastic) to singe cowhides creates styrene vapors, leading to headaches and central nervous system issues.

In July 2019, The National Agency for Food and Drug Administration and Control (NAFDAC) warned the general public in Nigeria to minimize the consumption of Ponmo, made of imported raw hides from other countries. Imported hides were pre-treated with chemicals for the manufacturing of shoes, bags, and belts; and, therefore, not suitable for human consumption. The leather industry has been facing troubles in Nigeria due to the consumption of contaminated Ponmo.

The first USDA-approved Ponmo processing in the United States was started in 2019 at Robert M. Kerr Food and Agriculture Product Center, Oklahoma State University, by a processor Dr. Siewe (from Nigeria), with five processing steps. Sienging, scraping, soaking, cleaning, final scraping. (See figure 3). In the initial stages of processing, the sienging is performed using natural gas burners. Sienging with gas burners took more time and constant labor effort because of having hair on the hide. To slove this issue, my advisor, Dr. Timothy Bowser (Department of Biosystem and Agg Engineering at Oklahoma state university), designed steel plate scorching method as an alternative for gas burner sienging. We tested scorching the hies with heated steel plates at 371.1°C, 537.7C and 704.4°C. less time and complete removal of hair was observed at 704.4 °C (see apendix B). The main problem in manufacturing Ponmo is getting hair off from the rawhide. Jacob. L. Nelson (Meat specialist at Food and Agriculture Product Center, Oklahoma State University) and Dr. Roy Escoubas (Director of Food and Agriculture Product center, Oklahoma State University) believe dehairing the hides using chemicals and skinner equipment will add more value to the Ponmo processing.

This research project main aim is to manufacture edible beef skin (Ponmo) by scorching the raw hides using heated steel plates to replace the traditional method. Different dehairing treatments (chemical and mechanical) followed by steel plate scorching were performed to test the time and temperature difference employed by each treatment. We also, examined quality parameters i.e., texture, color and moisture between the developed treatments. A hedonic scale expert sensory analysis was conducted to identify the best treatment according to the client Dr. Siewe.

Four treatment methods, i.e., Mechanically dehaired, Skinned, Trimmed, and Chemically dehaired, were developed to test the hypothesis as listed below.

Hypothesis 1

Null hypothesis: The moisture % of developed treatments are significantly not different.

Alternative hypothesis: The moisture percentage of developedtreatments are significantly different.

Hypothesis 2

Null hypothesis: The CIE L*, a*, b* values of all treatments are significantly not different.

Alternative hypothesis: The CIE L*, a*, b* values of all treatments are significantly different.

Hypothesis 3

Null hypothesis: The CIE L*, a*, b* and hedonic scale sensory analysis of all treatments for general appearance and golden color are not significantly different.

Alternative hypothesis: The CIE L*, a*, b* and hedonic scale sensory analysis of all treatments for general appearance and golden color are significantly different.

Hypothesis 4

Null hypothesis: The hardness of all the Mechanically dehaired, Skinned, Trimmed, and Chemically dehaired treatments are significantly not different.

Alternative hypothesis: The hardness of all the Mechanically dehaired, Skinned, Trimmed, and Chemically dehaired treatments are significantly different.

Hypothesis 5

Null hypothesis: The texturometer hardness and hedonic scale sensory analysis for general appearance and golden color are not significantly different.

Alternative hypothesis: The texturometer hardness and hedonic scale sensory analysis for general appearance and golden color are significantly different.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The aim of this chapter is to provide the key concepts of this thesis. Firstly, a summary is given about the usage of different animal skins in the food industry. Secondly, dehairing methods through chemical, enzymatic, and other schemes will be described. After that, the hazards of making Ponmo (edible beef skin) will be discussed.

Hazards discussed will include food safety, environmental safety, and human safety.
Next, details about the processing steps involved in making leather will be discussed. Finally, quality parameters of Ponmo, like color, texture, and moisture, will be reviewed.

2.2 Edible products made from hides

Edible products can be defined as products that people can eat safely. A wide variety of animal skin has been habituated for consumption in some parts of the world. The consumption of skin from pork, beef, fish, goat, bovine, & chicken has a significant advantage in vitamins and collagen. Most of these animal skins are often used as ingredients in many food products to improve the quality and nutrition value.

2.2.1 Gelatin made from bovine hides

Gelatin is a high molecular weight polypeptide made of collagen, the essential protein segment of animal connective tissues incorporating bone, skin, and tendon (Ramachandran et al., 1968). Gelatins have a wide range of advantages in the food industry. Gelatin is used as an ingredient to improve the uniformity, elasticity & consistency of food products (Benjakul et al., 2009). Tonnages of gelatin have been accounted for every year in various food products like candies, bakery products, ice cream, jellied meat, desserts, and dairy products (Djagny et al., 2001).

The overall production of gelatin in 2007 was around 326,000 tons, of which 46% were from pigskin, 29.4% from rawhide, 23.1% from bones, and 1.5% from different parts (Haug et al., 2011). Skins from bovine and are used to produce gelatin. Gelatins are extracted from beef and pork skins and bones by alkaline or acidic extraction (Jamilah et al., 2002). Skins from fish, like black tilapia and red tilapia, are used to produce fish gelatin (Jamilah et al., 2002). Because of some religious reasons and transmission of bovine spongiform encephalopathy ("Mad cow disease"), the use of gelatin from warmblooded animals was banned entirely in some countries (Gilsenan & et al., 2001).

2.2.2 Chicken skin as a fat reducing agent

Chicken sausage is one of the most popular meat products in the world (Barbut, 2016). A chicken sausage generally contains 20 to 35% fat, which plays a significant role in improving the eating experience (texture, juiciness, and flavor) of meat products (Cierach et al., 2009). Chicken skin contains 3% collagen (Cliche et al., 2003), where the smaller portions are integrated into meat emulsion or utilized as a wellspring of fat chiefly for soup preparation. Chicken skin is regularly utilized as a fat-reducing agent in meat items (Nath et al., 2016). Chicken skin has been utilized in the production of hotdogs as a source of fat. It plays a significant role in improving the texture of the hot dog (A. S. Babji et al., 1998). Using chicken skin as a component of the raw material in processed meats is the high substance of fat cholesterol. The high-fat substance will affect the emulsion stability and binding stability and influence the final product's texture (A. S. Babji et al., 1998).

2.2.3 Utilization of pork skin

The pork skin was considered an edible byproduct of slaughter, accounting for about 3% to 8% of live animal weight (Ockerman et al., 1994). It is also commonly used as a raw material for collagen and gelatin production (Nollet et al., 2011). Products derived from skins are used in human foods, cosmetics, and drugs.

The United States department of agriculture (USDA) has determined that pork collagen can effectively reduce purge and increase meat sausages cooking yield. Standards for sausage formulation allow the use of binders, mainly in standardized cured pork, non-standardized meat, and poultry products (USDA, 2001).

Hydrolyzed beef and pork skin may be added to hot dog emulsions as an alternative to non-fat dry milk. Hydrolyzed beef and pork skin impart a higher emulsification stability and higher binding capacity to fat and water than non-fat dry milk (Satterlee et al., 1973). A study by (Osburn et al., 1997) found pork skin connective tissue's waterbinding capacity was evaluated. The pork skin connective tissue is heated to 700°C, and the resulting gel has increased water-binding power and hardness. In contrast, when the proportion of pork skin connective tissue gel used in bologna is 10% to 15%, the bologna's hardness decreased, and the juiciness increased.

2.3 Dehairing

The process of separating hairs from raw hides by subjecting them to chemical and mechanical treatments is called deharing. There are many ways to dehair cattle, i.e., Chemical dehairing, enzymatic deharing, and some other treatment methods as explained below,

2.3.1 Chemical Dehairing

The process of separating hairs by applying chemicals, i.e., sodium sulfate, hydrogen sulfate, hydrogen peroxide organic sulfates, and other depilatory substances with respect to time and temperature & pH is called chemical dehairing. To comply with the final rule of pathogen reduction, Hazard Analysis, and Critical Control Points method in meat and poultry processing, most commercial companies follow various carcass decontamination methods to reduce pathogens (Bowling et al., 1992). The hides and feces were identified as the primary source of bacterial contamination on the carcass because of the fecal contamination on the animal's outer surface while holding (Hardin et al., 1995).

2.3.1.1 Dehairing by using sodium sulfite and hydrogen peroxide

A dehairing process using chemicals such as sodium sulfite and hydrogen peroxide was proposed and patented by Bowling and Clayton. (Bowling et al., 1992, 5, 149,295). Chemical dehairing was employed in reducing the microflora of beef hide. Large reduction rates were observed because of 10% sodium sulfide and the consequently high pH of the solution (Castillo et al., 1998). The process of dehairing has been explained by Bowling and Clayton as follows. The hide pieces were exposed to chemical dehairing initially by water pre-rinse for 90 seconds with a non-corrosive polyethylene sprayer. 10% of sodium sulfide was applied for 16 seconds then rested for 90 seconds, allowing sulfide to act on the hides. Again, 10% sodium sulfide was used for 16 seconds, followed by rest for 90 seconds. The hides were then cleaned with water, and 3% hydrogen peroxide was applied to the hides for 17 seconds, which neutralizes the sulfides on the hides. The hide pieces were then rinsed with water at 40° to 50°C, followed by the application of 3% hydrogen peroxide for another 17 seconds. At the final step, the hide pieces were again washed with water at 40° to50°C.

The significant reductions of E. Coli O157: H7, Salmonella, and Listeria monocytogenes were observed by following the hide samples' chemical dehairing process Castillo et al., 1998). (Nou et al., 2003 and Schnell et al., 1995) reported no significant change in aerobic plate counts and coliforms by chemical dehairing compared with conventionally slaughtered beef. However, the author said that the chemical dehairing improved the visual appearance but a low-level performance to reduce bacterial count was observed.

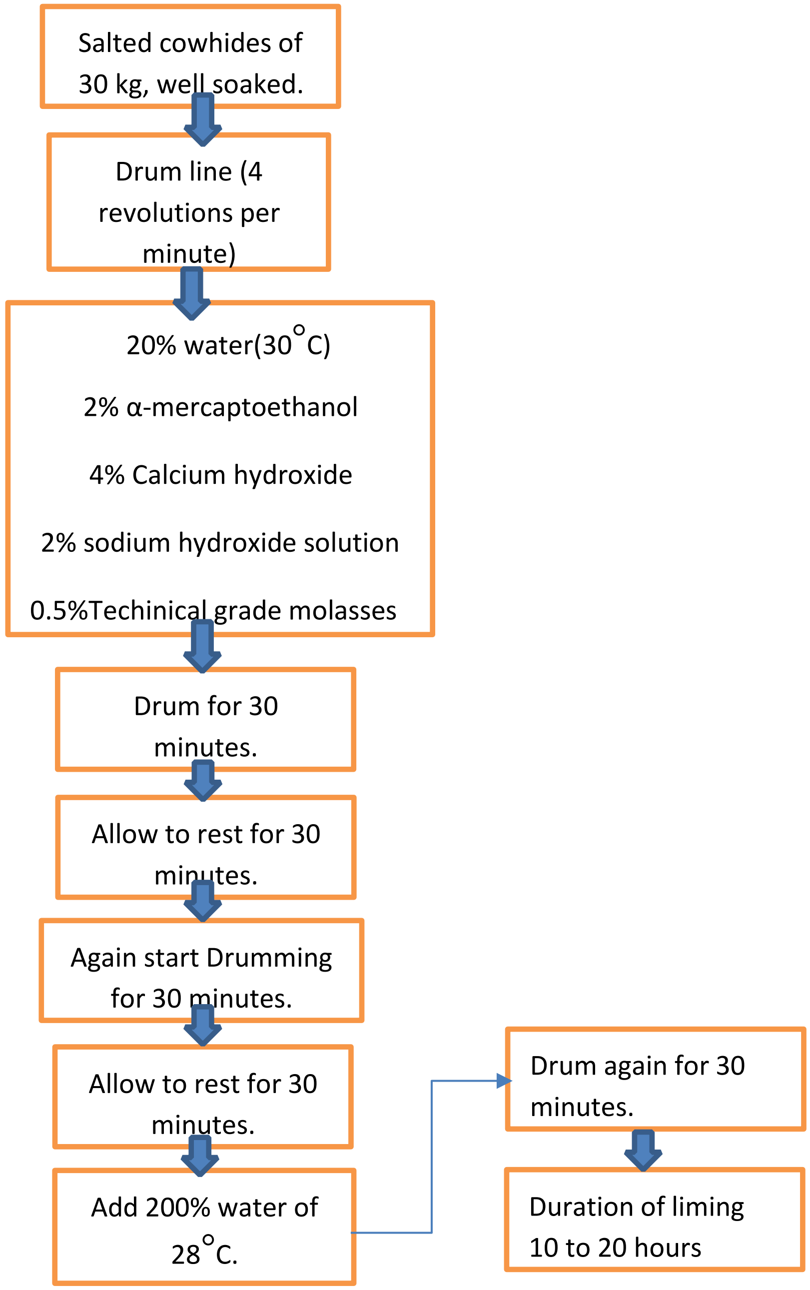
2.3.1.2 Dehairing with organic sulfur compounds

There are three types of organic sulfur compounds used in commercial hide dehairing systems, such as mercaptoethanol, salts of mercaptoacetic acid (thioglycolic acid), and formamidine sulphinic acid. These three chemicals are strong reducing agents that act like sulfides in dehairing processes but are expensive than sulfides.

A drumming procedure to remove hair from an animal's skin by using sulfur compounds in the occupancy of alkali and alkaline metal hydroxides in the presence of air and liquor was explained and patented by (Eckert et al., 1979, 4,175,922). The dehairing process undergoes the drumming of skins within the air in alcohol of 10 to 50 parts by weight with reference of 100 parts rawhide weight. The alcohol contains 1 to 2 parts by weight with reference of 100 parts weight of rawhide followed by 2 – 4 parts of α or β-Mercaptoalkanol (with 2 to 6 carbon atoms) by the reference of 100 parts of rawhide weight, of a soluble base or the basic earth metal hydroxide. The author attached an example procedure to dehair the salted beef hides. (See figure 1).

After dehairing more than 8 hours, only trace amounts of sulfide ions are detectable with cadmium acetate. (Miller et al., 1979).

Example



1. Procedure of dehairing salted beef hides using organic sulfur compounds. (Eckert et al., 1979, Patent no 4,175,922).

2.3.1.3 Selection of different depilatory substances

The selection of depilatory substances depends on the intended use. The depilatory substance to remove hair from animal skin can be sodium sulfide or potassium sodium sulfide; a mixture of thioglycolic acid, calcium oxide, sodium hydroxide; sodium hydroxide, and hydrogen peroxide or hydrogen peroxide and potassium hydroxide. The concentrations and the contact time (dwell time) are the critical factors that must be considered to save the hide from damage.

After applying dehairing chemicals, the hair can be removed by high air pressure air or some other mechanical method (Potter et al., 2002).

1. Different depilatory substances with their concentrations for chemical dehairing

Depilatory substance	**concentration**	**Dwell time & temperature.**	**pH**
Sodium sulfide Hydrogen peroxide	9% - 12%	Spray - 1 to 60 Seconds Left – 1 to 180 seconds Temp: below 48.8°C	9.5 - 12
Potassium sodium sulfide Hydrogen peroxide	10% - 15%	Spray: 1- 25 Seconds. Left: 20 -200 Seconds. Temperature: below 48.8°C.	Above 10 preferably; greater than 11.
Sodium hydroxide & hydrogen peroxide	13% – 15% & 4% – 6 %	Temperature: below 48.8°C.	Above 10 preferably; greater than 11.
Potassium hydroxide& Hydrogen peroxide	13% – 15% & 8% - 12%	Temperature: below 48.8°C.	Above 10 preferably; greater than 11.

Thioglycolic acid & calcium oxide & Sodium hydroxide.	8%- 11 & 1% – 5% & 1% – 5 %.	Temperature: below 48.8°C. Agitate for two hours 30 minutes.	Above 10 preferably; greater than 11.

2.3.1.4 Liming

Liming is used to remove the hair and flesh from a hide. The process of conventional liming undergoes the use of lime and sodium sulfide to remove hair (Riffel et al., 2003). The disulfide linkage in cysteine separation leads to the demolition and partial melting of the hair.

During the dehairing process, a large amount of water and toxic chemicals (such as sulfides) may be used. The wastewater must be treated, and solid waste should be recovered for reuse or treated to overcome soil pollution and water pollution (Dettmer et al., 2011).

2.3.2 Enzymatic deharing

The combination of lime and sodium sulfide leads to a high pollution burden on the environment because of the effluent's chemical biochemical oxygen demand (Sundararajan et al., 2011). Enzymatic dehairing has been developed to replace the conventional dehairing process (Sundararajan et al., 2011).

The usage of proteases follows the enzyme-based dehairing process to split the bonding material that holds the hair to the skin to get the complete hair out of the skin without smashing (Dutta et al., 1985). The alkaline protease from Bacillus cereus

VITSN04 was used for dehairing goatskin in leather processing. A serine alkaline protease from alkaliphilic Bacillus altitudinis gvc11 has been used as a dehairing agent for goatskin in 18 hours without affecting collagen (Kumar et al., 2011). The alkaline proteases produced from Bacillus licheniformis RP1, grown on shrimp, can be used as a dehairing agent for bovine hides under staking conditions with less damage to collagen (Haddar et al., 2011). The mixture of proteolytic bacteria enzymes from Streptomyces griseus was used in the dehairing of bovine hides. This process was a replacement for the burning hair (Gehring et al., 2002).

A method of ultrasonic treatment has been applied directly to skins and hair of different thicknesses. Soaking the hides in water allows the skins to swell, followed by adding a wetting agent and antiseptic substance, upon treating the hides with ultrasonic waves results in dehairing skins (Paul et al., 1960).

2.3.3 Other dehairing methods

Wet, untanned hides are subjected to an electrolytic solution (example: 1% NaOH, 30% Methanol), (3% LIOH, no alcohol) for about 10 minutes at a pH of 7 on the hair side, followed by allowing a direct current of (12volts, 3 amp), (6volts, 3 amp) by placing the cathode on hair side and anode on flesh side results in loosening of hair follicles.

These loosened hair follicles are removed mechanically (Whitmore et al., 1950).

Dehairing is a standard process followed by most United States meatpackers to remove swine hair. Carcasses are burned at 30°C then passed through dehairing equipment. The carcass is subjected to flames that singe the carcass's excess hair.Muscle quality was the main disadvantage of this process because it could speed up postmortem glycolysis (Carr, 1985). This results in low pH at high body temperatures, which leads to protein denaturation. The heat that was absorbed during scalding and dehairing can be eliminated rapidly once the scalding and heating were done (Van der Wal et al., 1993). When the carcass surfaces are subjected to heating, cut muscle surfaces were bleached (Gill et al., 1997).

2.4 Potential hazards of making Ponmo

2.4.1 Food safety

It has been assessed that food-borne infections cause 76 million diseases, and 325,000 were hospitalized; furthermore, 5,000 life destroys (approximately) every year in the United States (R. T. Bacon et al., 2002). The major food-borne infections are because by bacterial or viral etiology. Foodborne disease symptoms result in mild gastroenteritis, life-threatening neurological disorders, hepatic and renal syndrome. Consumer awareness plays a crucial role in the quality and public health inspection. Two hundred known diseases were spread through food (Bryan et al., 1982). Many foodborne illnesses are caused by foodborne pathogens that have not been identified or diagnosed (Mead et al.,

1999).

Beef hides are identified as the carcass's major cross-contamination source (Terrance M. Arthur et al., 2007). During the hide removal procedure, the hides' bacteria can move to underlying sterile carcass tissue (BE. Baird et al., 2005). To reduce microbial contamination levels, the slaughter processors have installed carcass wash cabinets in the slaughter lines and dressing lines (Delazari et al., 1998). The most prevailing microorganisms, i.e., E.coli O157, Salmonellaspp, Listeriaspp,

Campylobacterspp, are carried in the guts of the cattle and present in the feces of the cattle (Chapman et al., 2001). Strains of salmonella are accounted for 9.7% of total foodborne diseases (R. T. Bacon et al., 2002). Where E.coli O157 and non-O157 strains account for 5% and Campylobacterspp for 17% of pathogenic deaths were reported (M. Koohmaraie et al., 2005). Most of the beef processing plants in the United States implemented HACCP plans to mainly focus on decontamination of the carcass by steamvacuuming, acid rinse, hot water, and steam sprays (Xiangwu et al., 2013).

Hide's outer surface was exposed to dust, dirt, fecal material, which is a primary source of contamination. This can be controlled by washing with water, brushing, and drying methods. Poor sanitation practices are the reason for product spoilage, and the preservatives' failure increases the foodborne pathogens such as salmonella spp. and E Coli O157: H7 (Sofos et al., 1994). The food safety inspection system (FSIS) of the United States Department of Agriculture (USDA) passed the "Zero tolerance" rule where all visible waste on a red meat carcass, which does not associate with muscle or fat, should be trimmed before washing to deliver the clean product to the consumers (FSIS 1993). A crucial step in the slaughtering process is to follow sanitary guidelines to minimize carcasses' physical and microbiological contamination.

The national academy of sciences issued a series of alternative new approaches that ensure meat and poultry products' safety. The new process would depend on sciencebased risk assessment and prevention to comply with the current carcass-by-carcass inspection system (Unnevehr et al., 1999). The preventive approach is based on a set of principles known as Hazard

Analysis and Critical Control Point (HACCP) (Unnevehr et al., 1999). The food industry widely follows HACCP to improve good production and manufacturing practices (GMP) to produce safe food (Pierson et al., 2012).

2.4.2 Personal safety

Daily work in dangerous conditions is a threat to human health (Shikdar & Sawaqed, 2003). Workers may be exposed to toxins, radiation, vibrations, and low indoor air quality, leading to asthma, silicosis, allergies, deafness, lung diseases, eye diseases, and infections (Hnizdo et al., 2001).

According to some research results, people engaged with firefighting, mining, and construction suffer from sleeping disorders, heart diseases, traumatic diseases, muscle & skeleton disorders, and injuries that lead to death (Chen et al., 2007). Workers who are directly involved in the hide singeing activity at the abattoir are reported to contract eye and oculo-visual symptoms. In a slaughterhouse, workers near open fire and heat sources may be affected by the formation of crystalline lens clouding and corneal diseases, which influences their vision. Direct exposure of workers with allergens in the slaughter floors results in teary eyes, itchy eyes, and burning sensations (Wilson et al., 2008). Managers receive complaints from the workers affected with back pain, upper body and neck pain, hand soreness, and fatigue. A study (Shikdar et al., 2003) reported that, improperly designed machines and poor work area design (such as inappropriate heights) normal standing and sitting positions were impossible.

2.4.3 Environmental safety

The potential risk of heavy metal contamination in meat catches greater attention to food safety and human health because metals may be toxic in small concentrations (Santhi et al., 2008).

Dioxins are a group of persistent and toxic chemicals like furans, polychlorinated biphenyls, where each toxic chemical shares the chemical structures and biological properties (Dabuo et al., 2011). Cow skins dehaired by traditional singeing are exposed to toxic organic compounds, i.e., Dioxins, benzene, and polyaromatic hydrocarbons (dada et al., 2018). Polycyclic aromatic carbons are evolved because of the partial combustion of petroleum products and garbages. Compared to other traditional methods, singeing cowhides has potential contamination loads like metals (Ekenma K et al., 2015). Singed cow meat wastewater is genotoxic and harmful to the environment. (dada et al., 2018). The USEPA (the United States Environmental Protection Agency) categorized benz(a) anthracene, benzo(a)pyrene, dibenz(a,h) as carcinogenic PAH (USEPA, 1993). So, the cowhides exposed to any type of smoke can be contaminated with PAHs and lead to humans' potential health effects. However, (Odiba John et al., 2017) concluded the

PAH% were either below 50% or absent in roasted cow skins.

The tanning industry is considered as a major wastewater pollutant, which leads to potential environmental concerns. Tannery waste contains a complicated mixture of both organic and inorganic pollutants (Mwinyihija M et al., (2010). Rehydration of salted hides discharge unpleasant odor of different amino and fatty acids biological decomposition (J Kanagaraj et al., 2016). Treatment of animal skins to prepare the raw material for leather processing uses a bulk amount of chemicals and water results in generating high pollution loads. Sodium sulfide is one of the dangerous materials used to dehair the hides, results in hydrogen sulfide gas into the atmosphere (Dima W. Nazar et al., 2005). This is a toxin gas with an irritating odor, results in respiratory irritation and paralysis problems in humans (Mwinyihija M et al., 2010).

2.5 Other use of hides

2.5.1 Leather industry

The leather industry's main aim is to convert the animals' hides or skins into physical and chemically stable matters to meet human requirements. Hides are byproducts of the meat industry and become raw materials for the leather industry (Langmaier et al., 1999). The leather industry has a bad record of discharging pollution during the traditional manufacturing process because of high water consumption, organic waste, and odor (Haile et al., 2018).

The overall manufacturing process of leather from rawhides is explained in four steps (Dima et al., 2005) as listed below.

1. Beam house process
2. Tanning process
3. Post tanning process
4. Finishing process.

1. Beam house process:

The preserved hides were passed through the trimming process, where the unwanted portions are removed, and then these hides are soaked in water to restore moisture and remove blood and dirt. After soaking, the wet hides are fleshed to remove tissue and fat.

Next, they are treated with lime ($Ca(OH)_2$) and sodium sulfide (Na_2S) to remove hair and wool. The hides are swelled by subjecting them into a strongly alkaline solution bath to open the collagen structure. Again, these hides are passed through the fleshing process to clean the remaining flesh from the hide. At this stage, the hides are divided into two or three layers, called the splitting process. To remove the lime from the skin, a de-liming process is incorporated to decrease the pH level for subsequent steps. By allowing hides to batting process, these are subjected to enzymatic effect to open the structures and eliminate unwanted protein. After the batting process, a degreasing process is applied to hides to get rid of excess natural fat.

2. Tanning process:

At this processing step, the hides are treated with a solution consisting of salt and acid to get a homogeneous distribution of the material. Pickiling is the process of improving the acidity of the hide to a pH of 3 by adding salt and acidic liquor. By the addition of salt and acid liquor, Pickling increases the acidity of the hide. During pickling, salts are added to prevent the hide swelling (Salhma Ahmedh et al., 2013). After pickle processing to get thermal stability, various tanning substances are applied to the hide, tanning medium such as syntans, mineral tanning materials, and vegetable tannins are used.

Among all the tanning mediums, chrome, aluminum, and vegetable tanning are highly preferred because of their unique leather features. After this, to get the estimated thickness for the leather, the chrome shaving is done. Most of the lighter-weight cattle hides and the leather made from sheep, pigs, and goats follows chrome tanning procedures (Salhma Ahmedh et al., 2013).

3. Post tanning:

After the first tanning process, tanning is repeated. Re-tanning agents are processed on the leather to develop the texture and color characteristics of the leather (Everton Hansen et al., 2020). At this stage, the structural differences are remodified to obtain a uniform structure for the leathers. By using various mixtures of fat-liquoring agents on the leather, the material will achieve the desired flexibility and softness. Then the leathers are dried by hanging, and then the dyeing process is applied to the leathers to obtain the desired colors. Leather is made ready for final processing by trimming.

4. Finishing process:

Once the leathers are processed through fat liquoring and dyeing, they are coated with substances to improve resistance to the elements and improve appearance. At the final stage, the leather is shaped and sent for manufacturing into articles for sale.

2.6 Induction heating

Induction heating is a process used to rapidly heat electrically conductive materials such as copper, silver, gold, stainless steel, iron, and aluminum by electromagnetic induction (Semiatin et al., 1988). Generally, electromagnetic heating is used to preheat metals before welding and metalworking. It is also used for heat-treating metals.

Induction heating has a more significant advantage in many applications, such as forging and surface hardening of gears, shafts, and rolling of slabs and sheets, annealing strips, and vacuum induction melting of clean steels and superalloys (Semiatin et al., 1988). In 1981, the English physicist Michael Faraday found a basis for heating metal plates by induction heating. He stated that the electric energy could be produced by changing the magnetic field between two coils even though there is no physical contact between them (Rudnev et al., 2017). Faraday's law of induction is explained as the electromagnetic force developed in the circuit is directly proportional to the rate of magnetic flux change concerning the circuit's time (Rudnev et al., 2017)

There are many possible methods to heat a metal plate, including gas furnaces, salt baths, infrared heaters, fluidized furnaces, electric furnaces & bio-fuel fired furnaces (Semiatin et al., 1988). Induction heating devices that use gas and electricity as sources were used to heat the metal plates to control the workpiece's quality during manufacturing. The main advantage of induction heating is that the workpiece can be heated in a specific area (R.M. Baker et al., 1944).

Induction heating devices are divided into two types for heating the metals. 1. Longitudinal flow, and 2. Transverse flow.

In longitudinal flow heating devices, the metal plate is heated by supplying an alternate voltage to the induction-heating coil, resulting in a magnetic field. The workpiece is passed to the induction coil. Hence, two circumstances, such as eddy currents and magnetic hysteresis, heat the metal plate. Due to the Joule effect, the eddy

current oppose the magnetic flux, producing heat on the work plate. The magnetic hysteresis makes supplementary heating to ferromagnetic metals (Oscar Lucia et al., 2014). In this type of induction heating, if the current induced penetration depth is considerable and if the thickness of the work plate is thin, the induced current will be canceled on the worksheet's cross-section resulting in low heat (Hirota et al., 2013a). Because of its fast and controlled heating capacity, cheap cost, and high efficiency, the longitudinal heating type was mostly preferred in industrial, domestic, and medical industries (Oscar Lucia et al., 2014).

In the transverse flux heating system, the metal plate is placed between two magnetic bodies, often called inductors, to which the primary winding is rolled. The main advantage of using a transverse heating system is that the plate heats regardless of its thickness. The inductors used are low magnetic resistance. These inductors can reduce leakage flux, so the maximum flux will be focused on inductors facing the front and backside of the workpiece, resulting in high heating efficiency and fewer losses (Hirota et al., 2013b). The transverse type's primary defect is uneven temperature distribution when the workpiece is not in the center, facing the inductors. There is a high possibility of temperature deviation on one of the inductors (Hirota et al., 2013a).

2.7 Quality parameters

2.7.1 Moisture analysis

In the food industry, the moisture content of food is the most frequent property measured. Many techniques have been developed to measure food moisture content based on cost, sensitivity, accuracy, and ease of operation. For a food scientist, moisture content plays a crucial role in defining microbial stability, food processing operations, quality of the food, legal and label requirements.

Foods are diversified subsistence containing different water attributes such as chemically bound, bulk water, and physically bound water. Sometimes the water in food is present in different physical stages like gas, liquid, and solid. The dry product, after removal of all moisture, can be called total solids (Bradley et al., 2010). Moisture is a priority quality factor in preservation, and it affects the stability of some products, such as

- Powdered egg
- Dried milk
- Dehydrated potatoes
- Spices and herbs
- Dehydrated vegetables and fruits.

Moisture analysis is identified as a quality factor for products like

- Jams and jellies
- Conventional and puffed cereals.
- Sugar syrups.

Moisture reduced concept is used in packaging and shipping of food products like

- Concentrated (Undiluted) milk.
- Undiluted fruit juices.
- Liquid cane sugar and dehydrated products.

There are many different methods used to analyze the moisture in food products, such as

1. Microwave oven method.
2. Conventional or forced draft oven method.

The evaporation method depends upon measuring the mass of the water in a known mass of the sample. The moisture content is calculated from the values of the mass of water before and after the removal from the food (DeMan et al., 1999). The amount of moisture content depends on the type of the oven, drying time, and temperatures.

$$\text{Moisture percentage} = (mw / m\ \text{sample}) \times 100.$$

Where mw = Mass of water, m sample = Mass of the sample.

The number of solid parts available measures the percentage of total solids after water evaporation (DeMan et al., 1999)

$$\text{Percentage Total solids} = (M\ \text{dried} / M\ \text{initial}) \times 100.$$

Microwave oven method:

Microwave ovens can be used to analyze the moisture content materials. The main advantage of microwave ovens is they will execute results quickly compared with convection type ovens. (5 minutes to 15 minutes when compared to 6 hours to 72 hours). A micro-oven method that requires 3.5 minutes of drying time when premixed with chemicals was developed (Pettinati et al., 1975). A simple microwave drying technique to analyze moisture analysis and increase drying speed was explained by (Lee & et al., 1976). Moisture readings obtained with microwave ovens are inaccurate. They cannot produce the same result as convection-type ovens do (Brusewitz et al., 1984).

Conventional or forced draft oven method:

The samples are weighed and placed in the oven for a specific time and temperature. (example, 24 hours at 50°C), and dried until they reach constant mass (Robert L et al.,2010). Great temperature differential exists in conventional type ovens. A 10°C across the conventional oven is not unusual.

A procedure for analyzing fat, moisture, and protein in meat and meat products by FOSS FoodScanTM incorporated with a near-infrared spectrophotometer with FOSS Artificial Neural Network (ANN) was explained in (39.1.38 AOAC official methods of Analysis 2007.04). A procedure for estimating moisture and fat in meats using microwave and nuclear magnetic resonance analysis was developed (39.1.39 AOAC

Official method 2008.06).

2.8 Color:

In quality assessment, color is an essential factor in the food and agriculture industries because it is closely related to freshness, food safety, desirability, and ripeness.

Color is a primary consideration for consumers while purchasing (McCaig et al., 2002). Identification of color using instruments like the spectrophotometer and colorimeter are widely used in many research fields such as food engineering, physics, hospitals, and biotechnology. Some important properties like color, solid content, oil content, acidity, and other food properties are detected using a colorimeter and spectrophotometer in the food industry (Kim et al., 2015).

The color of food products, like vegetables and fruits, is derived from natural pigments; they may change when the plant is subjected to maturation and ripening. The important pigments recounted for color quality are chlorophylls producing green color. Carotenoids produce yellow, orange, and red colors; flavonoids have a yellow color, water-soluble anthocyanins responsible for red and blue colors, and betalains account for red color (Barrett et al., 2010).

In 1986 Hunter L* a* b* was developed for photoelectric measurement, and the CIE L*a*b color space was introduced in 1976. Two instruments, the colorimeter, and spectrophotometer are efficient in analyzing color (AMSA, 2012). Most food industry practitioners use the Hunter Lab L*a*b* scheme along with CIELAB scales. The CIELAB parameters such as L*, a*, b* were detected directly by placing the sensor on the sample. L* is considered a psychometric index of light, and a*, b* are recorded as two coordinates of color.

The variable a* has positive values for the red color and negative values for the green color. Where b* has positive values for yellow color and negative values for blue color. L* estimates luminosity, where each color can be considered identical to grayscale (Granato et al., 2010). The spectrophotometer illuminates the sample reflected waves are allowed to pass through a monochromator or read by diode array. These values are sent through a microprocessor result in reflected spectra, where these values are converted into either CIE L*a*b* or in XYZ pattern (AMSA, 2012).

Several illuminants (for example, illuminants A, C, or D65) affect the color of meat products while measuring with instruments. AMSA guidelines for meat color evaluation suggest using illuminant A when analyzing many samples for a long time (AMSA, 2012).

Light sources such as C and D65 are used highly in many meat science publications with Minolta equipment (Tapp Iii et al., 2011). (Brewer et al., 2001), reported that the difference in the instrument might result in different color readings for the same sample.

2.9 Texture analysis

Texture is considered an essential sensory property. Food scientist Dr. Alina Surmacaka Szczesnaik developed the texturometer in the early 1960's . A dendrometer was used to analyze the mechanical properties of texture (Brody et al., 1956). Different food materials like potato chips, bread, dog foods texture were analyzed using a General Foods texturometer (Brenan et al. 1970).

There are different pieces of instruments used in analyzing various properties of texture. The shear-press, Tenderometers are used to analyze the tenderness. The Gelometer measures the stiffness(firmness) of gels, the consistometer and viscosimeter are used to estimate resistance to pass, and the compressimeters are used to analyze the hardness of the sample (Friedmanet et al., 1963). The overall mechanical properties can be investigated by using a denture tendurometer (Proctor et al., 1955). Strain methods like tension, puncture, bending, commercial analysis, and penetration are usually used to assess freshness and textural modifications depending on the storage conditions (Truong et al., 2003). These highly sensible and genuine techniques can detect slight changes basing on the formulation or storage timings.

While analyzing the mechanical characteristics of texture, the primary five parameters are hardness, cohesiveness, viscosity, elasticity, and adhesiveness. To make this consideration meaningful to the customers, mechanical characteristics are further classified into secondary parameters such as brittleness, chewiness, gumminess (Szczesniak et al., 2002). A popular test Texture profile analysis (TPA) was developed for assessing the general food texturometer. This test compresses a bite-sized food sample a couple of times in a reciprocating motion and produces time vs. force curves which come up with various texture parameters such as Hardness (Force (F2)), Adhesiveness (Area 3:4), Springiness (ratio of lengths) Gumminess (F3 × Cohesiveness),

Chewiness(Gumminess * Springiness) (Friedman et al., 1963).

Strain methods like tension, puncture, bending, commercial analysis, and penetration are usually used to assess freshness and textural modifications depending on the storage conditions (Truong et al., 2003). These highly sensible and genuine techniques can detect slight changes basing on the formulation or Storage timings.

2.10 Sensory analysis

Sensory evaluation is the recognition, scientific quantification, investigation, and simplification of a food sample's characteristics related to the process of consuming (also known as eating). They are recognized based on five senses of odor, flavor, sight, hearing, and touching. Sensory analysis can be either qualitative or quantitative (Carpenter et al., 2012).

The measurement will be based on an objective analytical quality like firmness or flavor strength or subjective value judgment like preference, acceptability, and fondness. The sensory analysis acknowledges query of product quality based upon discrimination, preference, description. A 1- 9- point Hedonic measuring scale is a highly preferred method to measure the range of liking by untrained panelists. The sensory analysis acts as a cost-effective resource that plays an effective role in developing a successful product (Mdziniso et al., 2002).

Sensory evaluation practitioners incorporate an extensive range of teachers and researchers in education, sensory professionals at consumer product companies. All food companies are currently maintaining product experts to deal with raw material quality and finished products (Cairncross et., al).

CHAPTER III

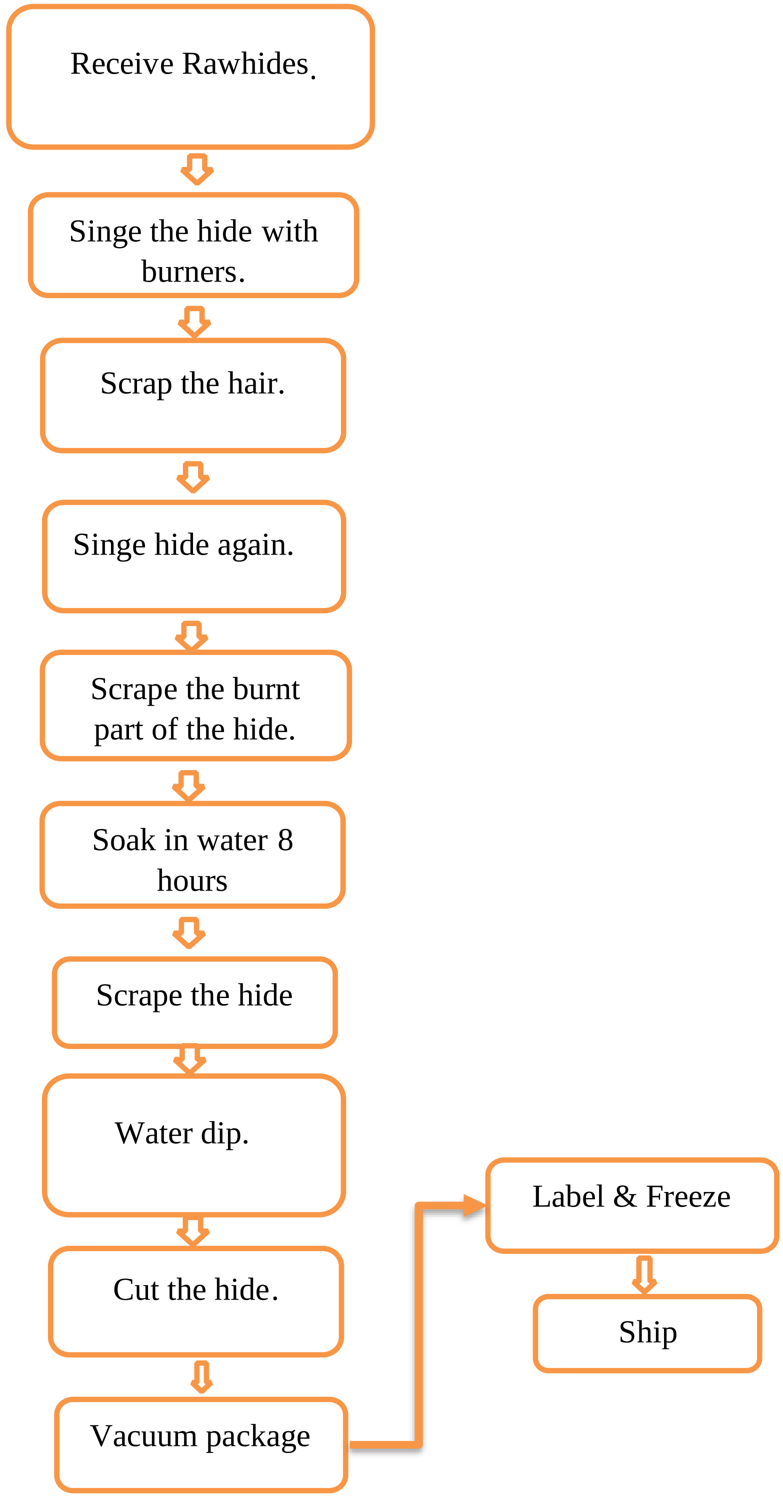
MATERIALS AND METHODS

3.1 Introduction

This section describes materials and methods used to process and evaluate beef hide. Materials are listed, including the specification and supplier/ manufacturer information. The overall methods used will be described using process flow diagrams, narratives of the flow diagrams, and photos.

Existing standards and procedures, when available, were adopted as methods of work. This section also identifies current standards and procedures and how they were applied, including necessary modifications.

Figure 2 is a generic process flow diagram of how to make Ponmo using traditional methods.


Receive Rawhides.
Singe the hide with burners.
Scrap the hair.
Singe hide again.
Scrape the burnt part of the hide.
Soak in water 8 hours
Scrape the hide
Water dip.
Cut the hide.
Vacuum package
Label & Freeze
Ship

2. Process flow diagram of manufacturing Ponmo using traditional method

3.2 The procedure of manufacturing edible beef skin (Ponmo) using traditional methods:

Rawhides were collected from the slaughterhouse at Robert M. Kerr Food and Agriculture Product Center, Oklahoma State University. The hides were cut into pieces using butcher knives and placed on a metal surface and well-singed using two natural gas burners until the hide gets an average temperature of 78°C (174°F), followed by scraping with butcher knives to remove the ash from the hide. The hides' temperature was measured using a calibrated thermometer (Thermapen Mk4 Thermometer, B7352990, Thermoworks, Utah, U.S.A.). During singeing, the hide started curling upon itself. The un-burned spots were identified during scraping, and the hide was subjected to singe again, followed by scraping with butcher knives. The well-signed hides were dumped in a barrel that contained ice water. The exact temperature of 0°C is maintained by placing ice in the barrel. The process of soaking hides in ice water was identified as a critical control point to control Listeria monocytogenes. This hides' processing was carried out at room temperature under an exhaust hood to capture and remove smoke produced during singeing.

These soaked hides in an ice water barrel was placed in a cold room at a temperature of 0°C (32°F) for 12 hours approximately. Then the hide pieces were scraped again with a butcher knife to remove ash and fat. After a thorough scraping, the hide squares were cleaned with hot water at a temperature of 48°C (120°F) by using tap water from a hose.

Then the hides were placed on a metal rack for approximately 15 minutes to drip dry.

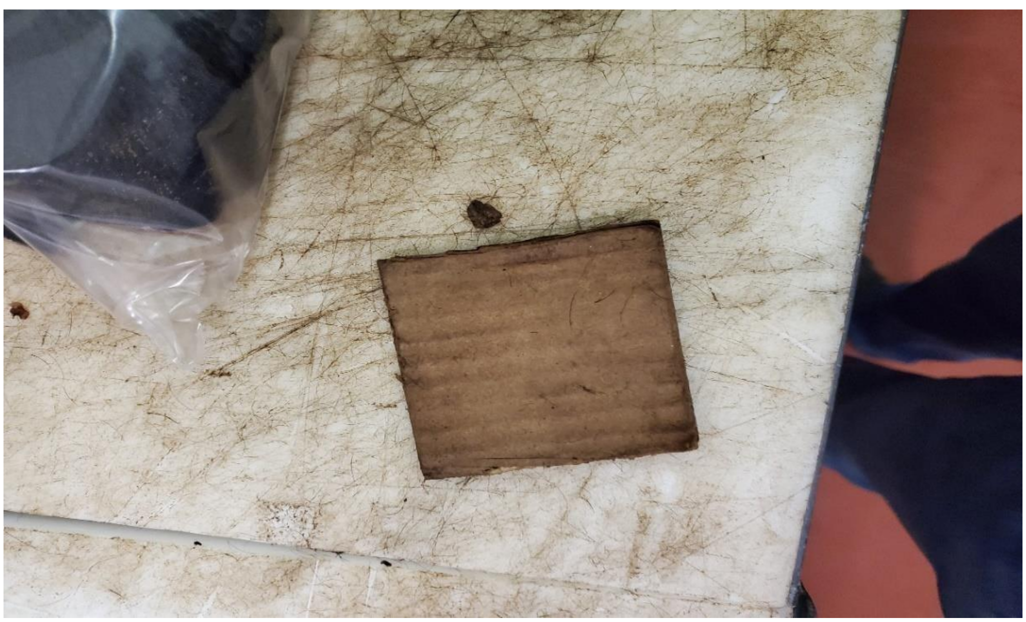
Finally, the hides were packed using a vacuum packaging machine (Multivac, modelC500, serial no- 116056, Germany) and then shipped to customers. The picture of vacuum packaged Ponmo is shown below (see figure 3). Utilities like natural gas and water, time, and labor utilized during manufacturing edible beef skin (Ponmo) are shown in appendix A.

A sample picture of vacuum-packed edible beef skin (Ponmo) is shown below

3. Processed vacuum-packed Ponmo

3.3 Sample preparation

Beef hide portions, taken from the area near the spine of the beef carcass, were collected from beef hides harvested at the Robert M. Kerr Food and Agriculture Product Center at Oklahoma State University. A cardboard piece was made into a 3-inch square, as shown in figure 4, was used as a reference to cut the hide pieces into 3-inch squares. Seven hide squares of 3-inch size were coded to perform each experiment phase (Mechanical, trimmed, skinned, and chemical dehairing). These hide squares were saved in 3.78L Ziploc® storage bags, as shown in figure 5, and stored separately according to the experimental phase. The individual bags were placed into a separate 7.75L Ziploc® bag, as shown in figure 6, and frozen for approximately 24 hours.



4. 3-inc Cardboard piece

5. 3-inch hide squares in 3.78L Ziploc® storage bags

:

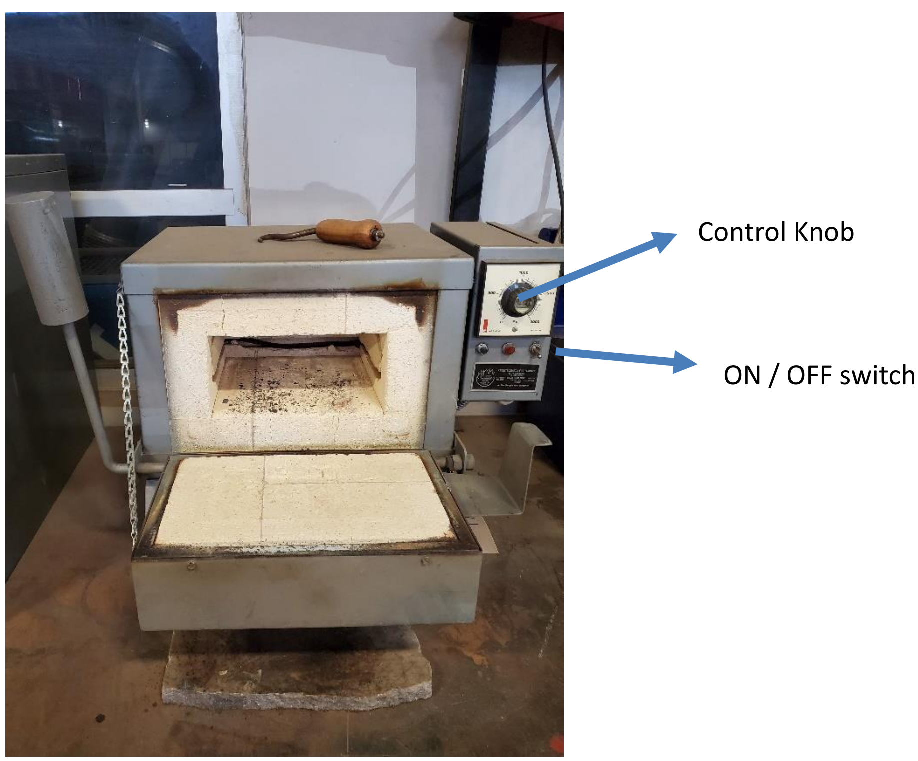
6. Rawhide samples saved in 7.5L Ziploc bag

3.4 Steel plate heating

Two steel plates of 127.00mm square with 50.80mm thickness were fabricated at the Biosystems and Agriculture Engineering Shop at Oklahoma State University. As shown in figure 7, the steel plate has four retention eyelets on both sides. Two tongs (fabricated at the Biosystem and Agriculture Engineering Shop at Oklahoma State University) were used to handle the steel plates. The tongs were inserted into the retention eyelets on the plates to enable safe handling. (Figure 8) shows an electric furnace (MT-9, Moore kiln company, Irving, Texas) that was borrowed from the Biosystems and Agriculture

Engineering Shop at Oklahoma State University. The temperature was set to 1037.7° C (1900°F). The two steel plates were placed inside the furnace using the tongs. The plates were heated at 704.4°C (1300°F), as shown in figure 9. A handheld thermocouple probe for surfaces (50319- K, Cooper Atkins, Chicago, IL, USA) was used to measure the plates' surface temperature. As the plate reaches 704.4°C (1300°F), the plates were removed from the oven and placed onto firebrick insulators.

7. Fabricated steel plates of 50.80mm thickness



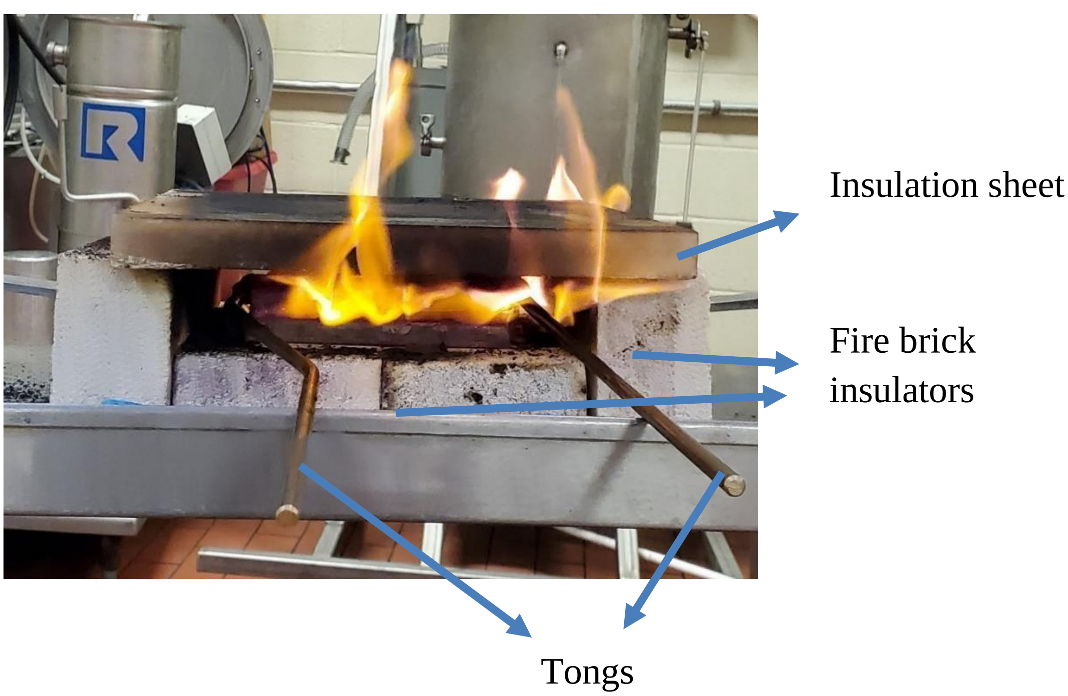
8. Fire furnace

9. Heating steel plates in an electric furnace

3.5 Scorching

At room temperature, the rawhide samples' initial weights and temperature were measured using a scale (MlXC4100, Denver instruments, Arvada, CO) and handheld thermometer (Thermapen Mk4 Thermometer, B7352990, Thermoworks, Utah, U.S.A.). Two flame-resistant fire brick insulators (BNG – 23 HS, Armil CFS, South Holland, Illinois, USA) were placed on the surface of a stainless steel work table, surrounded by two additional firebrick insulators. The heated steel plate was transferred onto the insulator bricks with the help of the tongs. The rawhide sample is placed on the heated plate, and the remaining plate was placed on top of the rawhide sample. A sheet of insulation (676057, SPI LLC, RYE, NY, USA) with dimensions of $6.4074e^{-7}$Kilogram/ cubic millimeter,25mm/4mm thick, 0.3048m wide, 0.3048m long was placed on top of the steel plates, as shown in figure 10, to reduce heat loss. After the second plate was placed on the rawhide a temperature probe (NH-06gs4kk2m, Electronic development labs, Columbia, Maryland) was inserted into the sample from the side to measure the hide's internal temperature. The internal hide temperature was recorded periodically. The overall scorching procedure was carried out under an industrial exhaust hood to capture smoke.

The above procedure was repeated to perform scorching for the four types of hide samples: Mechanically dehaired, Skinned, Trimmed, and Chemically dehaired.



10. Scorching experiment arrangement

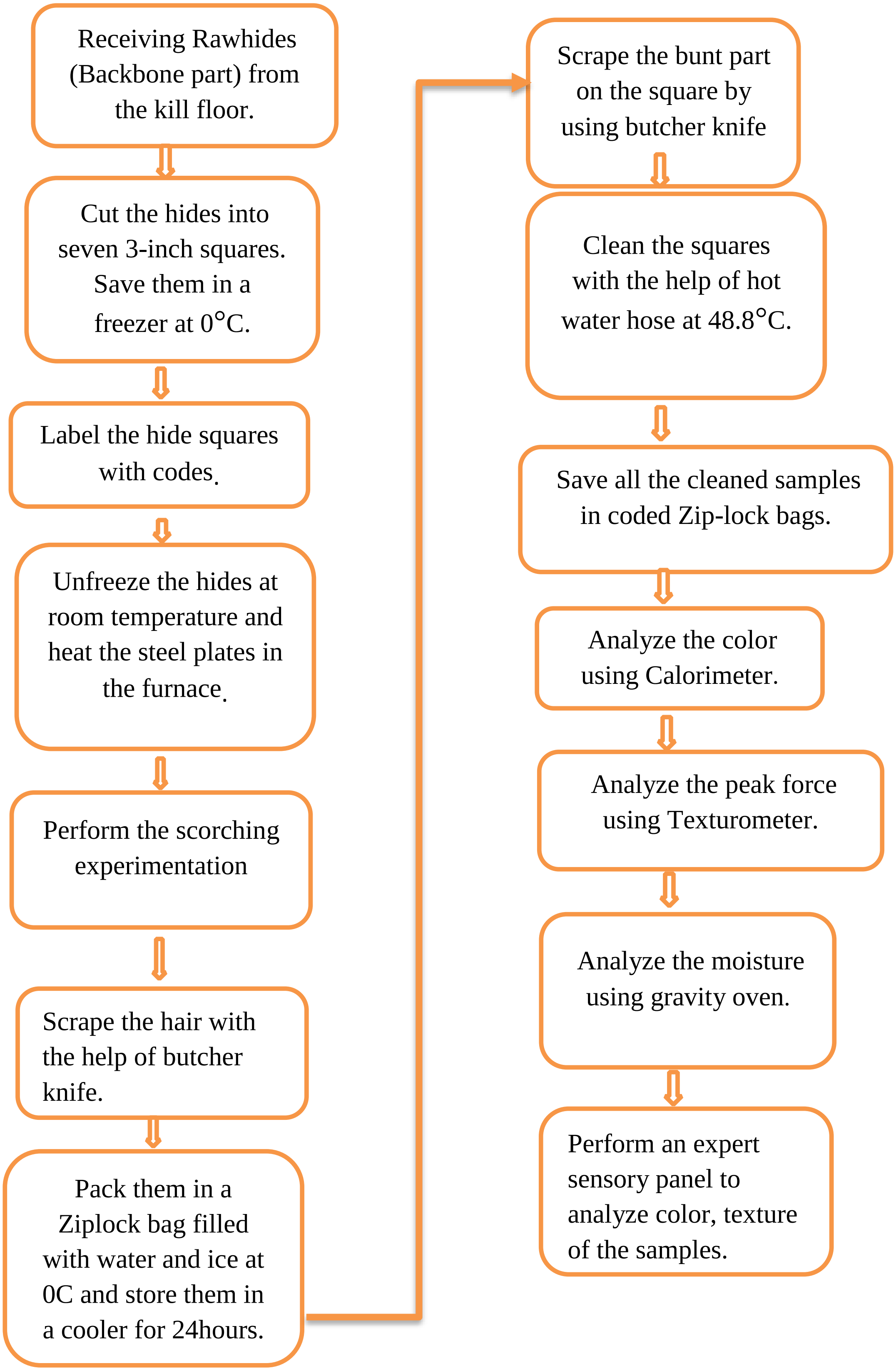
3.6 Description of hide-scorching methods

The experimental procedure was carried out on four different hide treatments

1. Mechanically dehaired
2. Trimmed.
3. Skinned.
4. Chemically dehaired.

3.6.1 Mechanically dehaired

Below shown (Figure 11) explains the process flow for mechanically dehaired treatment. Steel plates were heated at 704.4°C and the rawhides were scorched by placing between the heated steel plates (hair side down). The burnt part was scraped using a butcher knife, then each sample was coded and soaked separately in 3.7L ziplock bag (See figure 12), which are filled with ice and water. The samples were soaked for12 hours in a cold room at 0°C (32°F). Then, the samples were cleaned with hot water, followed by scraping the ash using butcher knives. Each sample was saved in a separate 3.7L Ziploc® bag to analyze the quality parameters.



11. Process flow diagram for mechanically dehaired treatment.

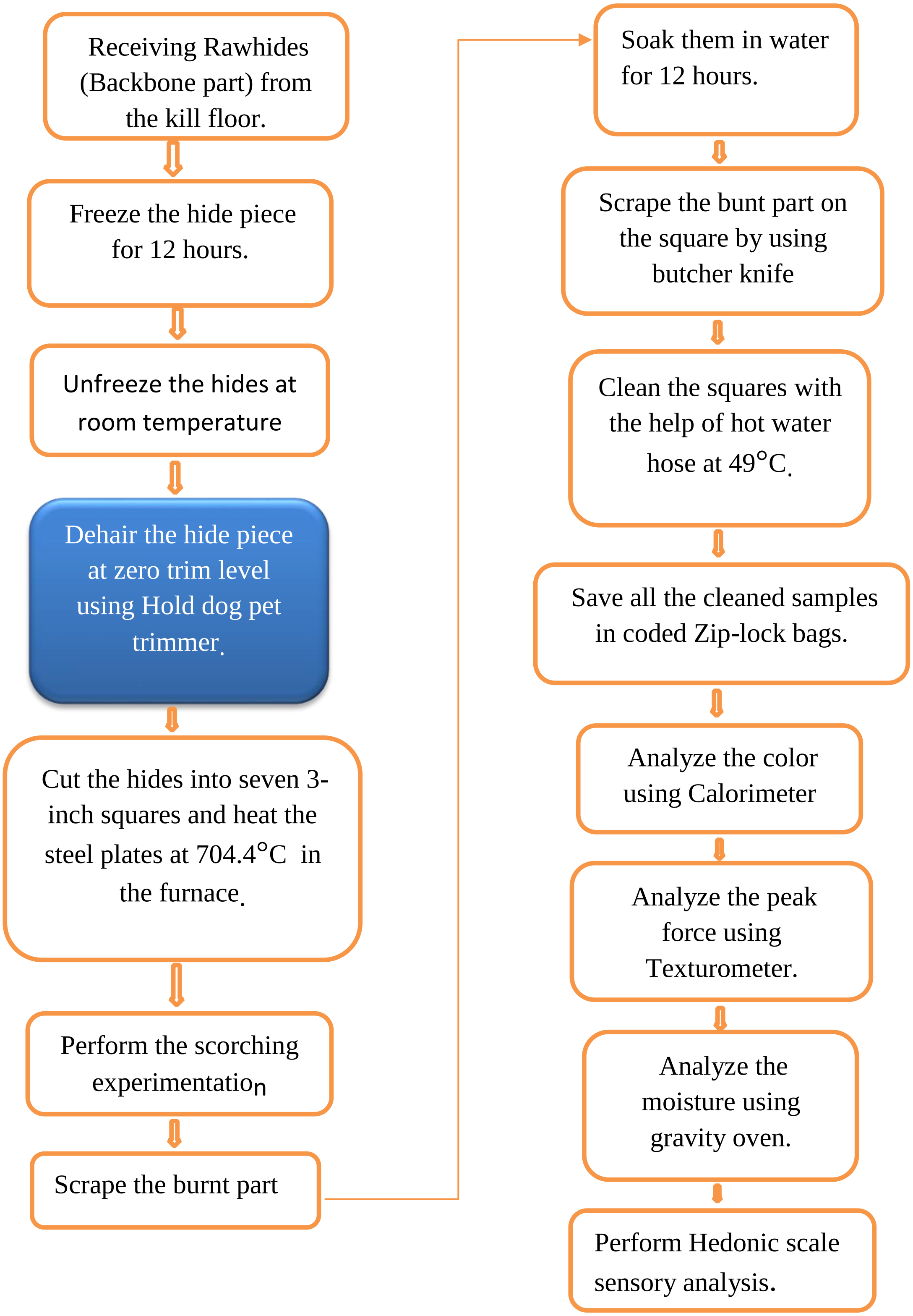
12. Soaking of samples in Ziploc® bags

3.6.2 Trimmed:

A professional heavy-duty Hold dog-grooming clipper was purchased through Amazon. A big hide piece was collected from Robert. M. Kerr Food and Agricultural product center at Oklahoma state university. Using the Hold dog clipper, the hair was trimmed to

0’. The big hide piece was then made into seven 3’ square samples using cardboard, as shown in Figure 4. Steel plates were heated at 704.4°C using a Moore kiln fire furnace

(Figure 9), and a scorching experiment was performed for each sample, as shown in figure 10. A k-type thermocouple probe was inserted into the hide samples to find the cooking temperature. The processed samples were saved in a 3.7L Ziploc® bag separately and soaked in water at 0°C (32°F) for 12 hours, as shown in figure 12, followed by scraping the burnt part using a butcher knife and hot water rinsing at 48.8°C using an industrial hose. The below-shown process flow diagram (see figure 13) explains the trimmed experimentation.

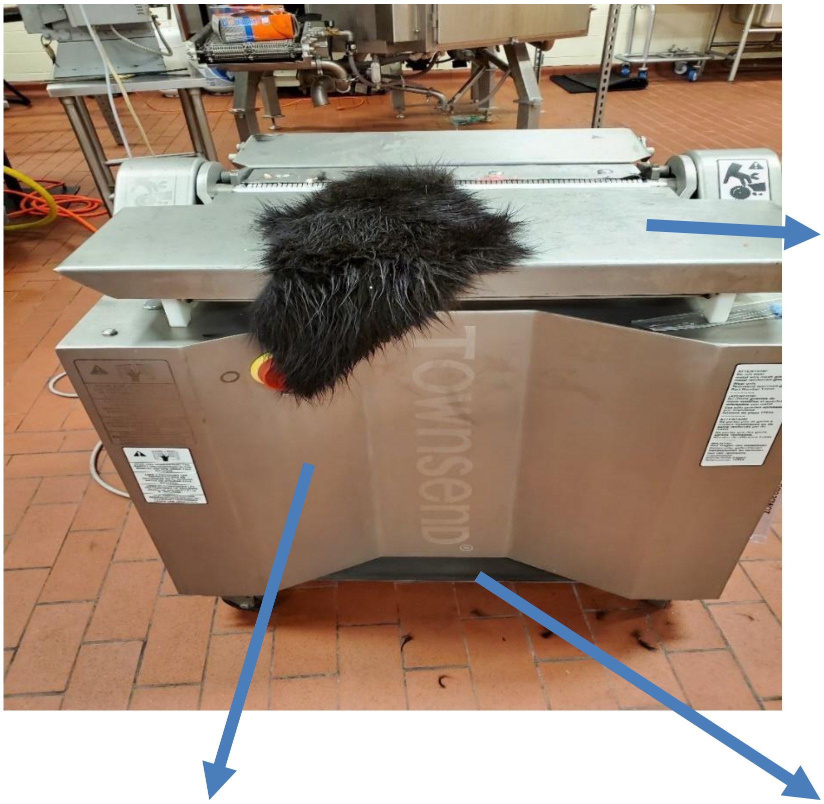


13. Process flow diagram for trimmed treatment.

3.6.3 Skinner equipment:

Membrane skinning equipment (Townsend Model 7600 skinner, Townsend Eng., Des Moines, Iowa, U.S.A) was used to dehair the beef hides, as shown in figure 14. Procedures outlined in the skinner manual were followed. Townsend recommended the use of 33.02cm skinner gloves throughout the procedure to avoid operator injury (See figure 15). A new blade was installed prior to skinning. The cut's thickness depends on the blade protrusion and the position was adjusted to obtain the desired thickness of the hide square. The blade protrusion was adjusted using the knobs on the rear side of the shoe. The excess membrane from the hide sample was trimmed off using a butcher knife. The hide pieces were washed with water prior to skinning. Skinned samples were collected and made into seven, 7.62 cm squares to perform scorching experimentation.

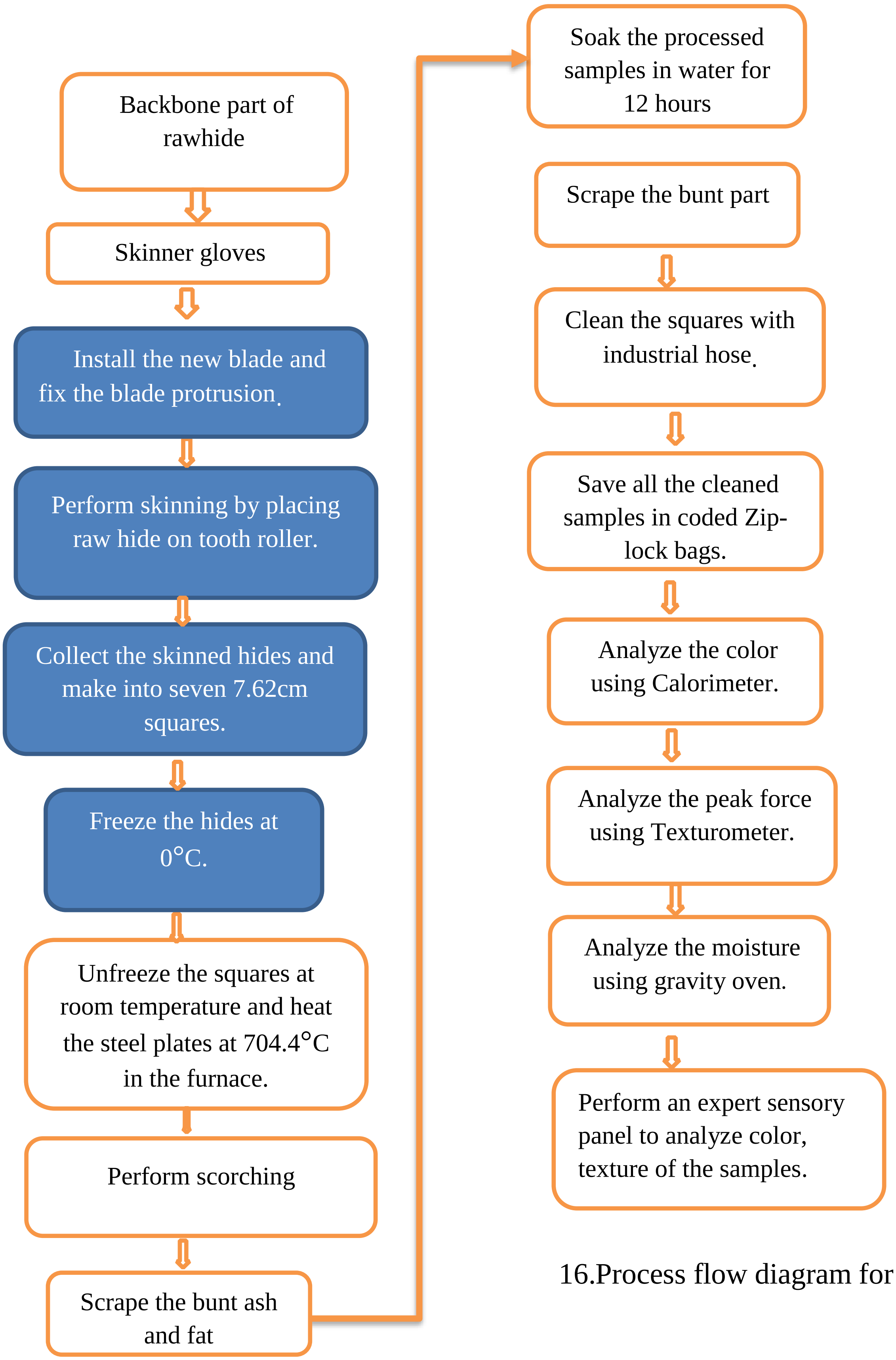
The processed samples were saved in a 3.78L ziplock® bags and soaked in water at 0°C (32°F) for 12 hours, as shown in figure 9. The samples were removed from the bags and the burnt parts were scraped off using a butcher knife. Hot tap water at about 49°C was used to rinse the scraped hide squares. The process flow diagram in figure 16 outlines the skinning process.



14. Marel Townsend skinner equipment

33.02cm skinner gloves

15. Townsend recommend membrane skinner glove.



16.Process flow diagram for skinned treatment

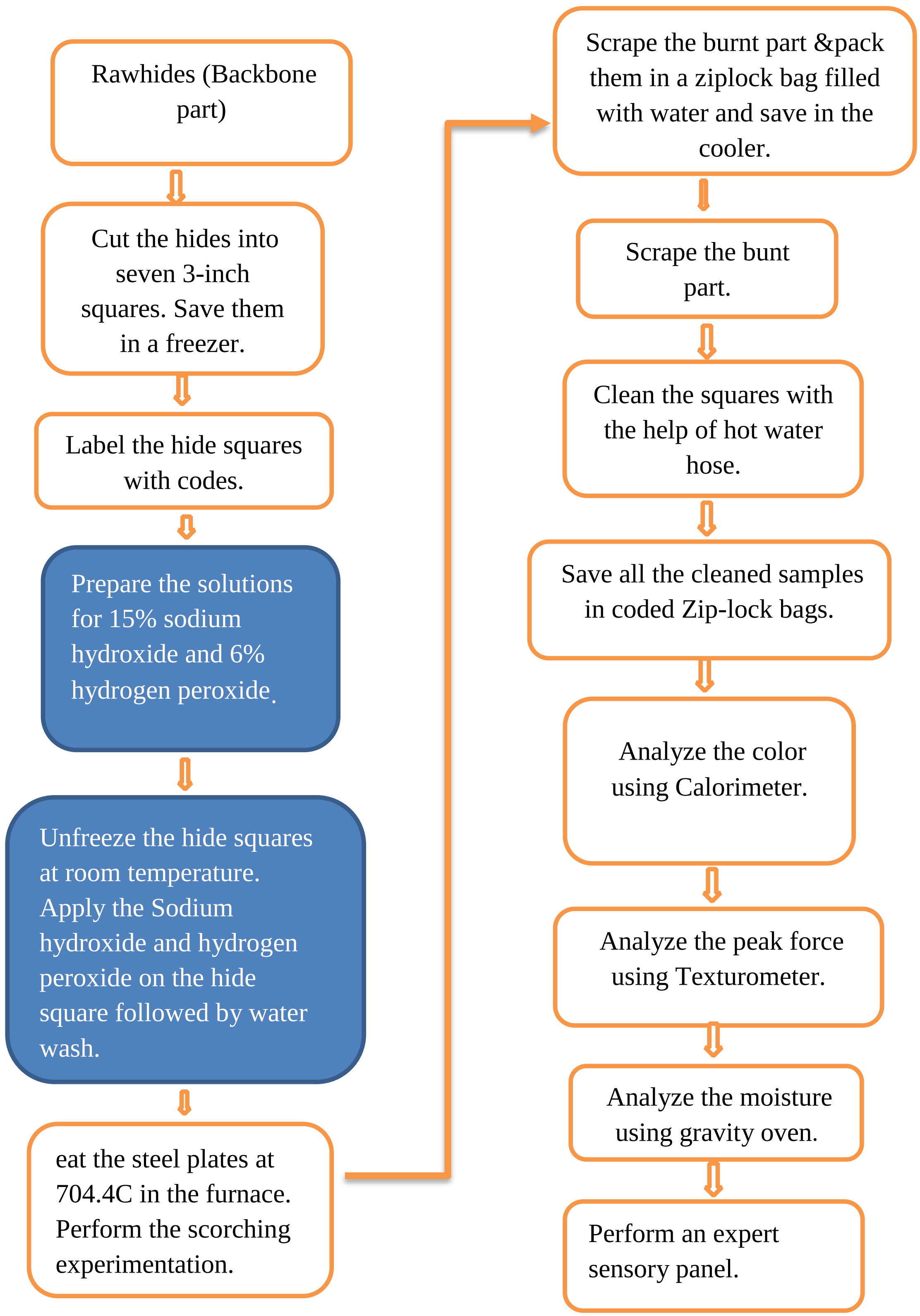
3.6.4 Chemically dehaired

3.6.4.1 Dilutions

Dain cleaner pellets, which approximately contain 100% sodium hydroxide were obtained from McMaster (J3719, Thrift, Livingston, TX, USA). The pellets were added to tap water to obtain a 13% to 15% sodium hydroxide solution. 300 grams of the pellets were weighed and added to 1700 ml of water in a glass flask. The pellets were dissolved for 5 minutes. A 6% lab-grade hydrogen peroxide solution was purchased from Amazon (IS17046, HBARSCI, Victor, NY). A 15% sodium hydroxide with 6% hydrogen peroxide is used to de-hair the hide squares (Potter et al., 2002).

3.6.4.2 Procedure

Seven replicates of rawhide squares were subjected to a chemical dehairing procedure by, pre-rinsing the sample with water for 90 seconds at a temperature of 49°C by using an industrial hose, followed by applying 15% of sodium hydroxide solution (Bowling et al., 1992) with the help of a handheld sprayer for 20 seconds and allowed it to react for 90 seconds. Again, the hide squares were rinsed with water for 40 seconds at 49°C, followed by the application of 15% sodium hydroxide for 20 seconds. Allow the sodium hydroxide solution to react for 2 minutes, followed by water rinse for 30 seconds. After this, 6% hydrogen peroxide solution was applied for 25 seconds and allowed to neutralize the sodium hydroxide for 60 seconds, water wash at 49°C. Finally, again 6% hydrogen peroxide was applied for 25 seconds and left for 60seaconds (Castillo et al., 1998). A butcher knife was used to scrape the treated hair. Steel plates were heated at 704.4°C using a Furnace (MT-9, Moore kiln company, Irving, Texas). A scorching experiment was performed, and the burnt part was scraped using a butcher knife. Samples were soaked in water at 0°C for 12 hours in Ziploc® bags (3.7L storage bags), as shown in figure 12, and stored in a cooler followed by scraping with a butcher knife and cleaning with hot water at 49°C. The below-shown process flow diagram (Figure 17) explains the chemical dehairing experimentation.


Rawhides (Backbone part)
Cut the hides into seven 3-inch squares. Save them in a freezer.
Label the hide squares with codes.
Prepare the solutions for 15% sodium hydroxide and 6% hydrogen peroxide.
Unfreeze the hide squares at room temperature. Apply the Sodium hydroxide and hydrogen peroxide on the hide square followed by water wash.
eat the steel plates at 704.4C in the furnace. Perform the scorching experimentation.
Scrape the burnt part &pack them in a ziplock bag filled with water and save in the cooler.
Scrape the bunt part.
Clean the squares with the help of hot water hose.
Save all the cleaned samples in coded Zip-lock bags.
Analyze the color using Calorimeter.
Analyze the peak force using Texturometer.
Analyze the moisture using gravity oven.
Perform an expert sensory panel.

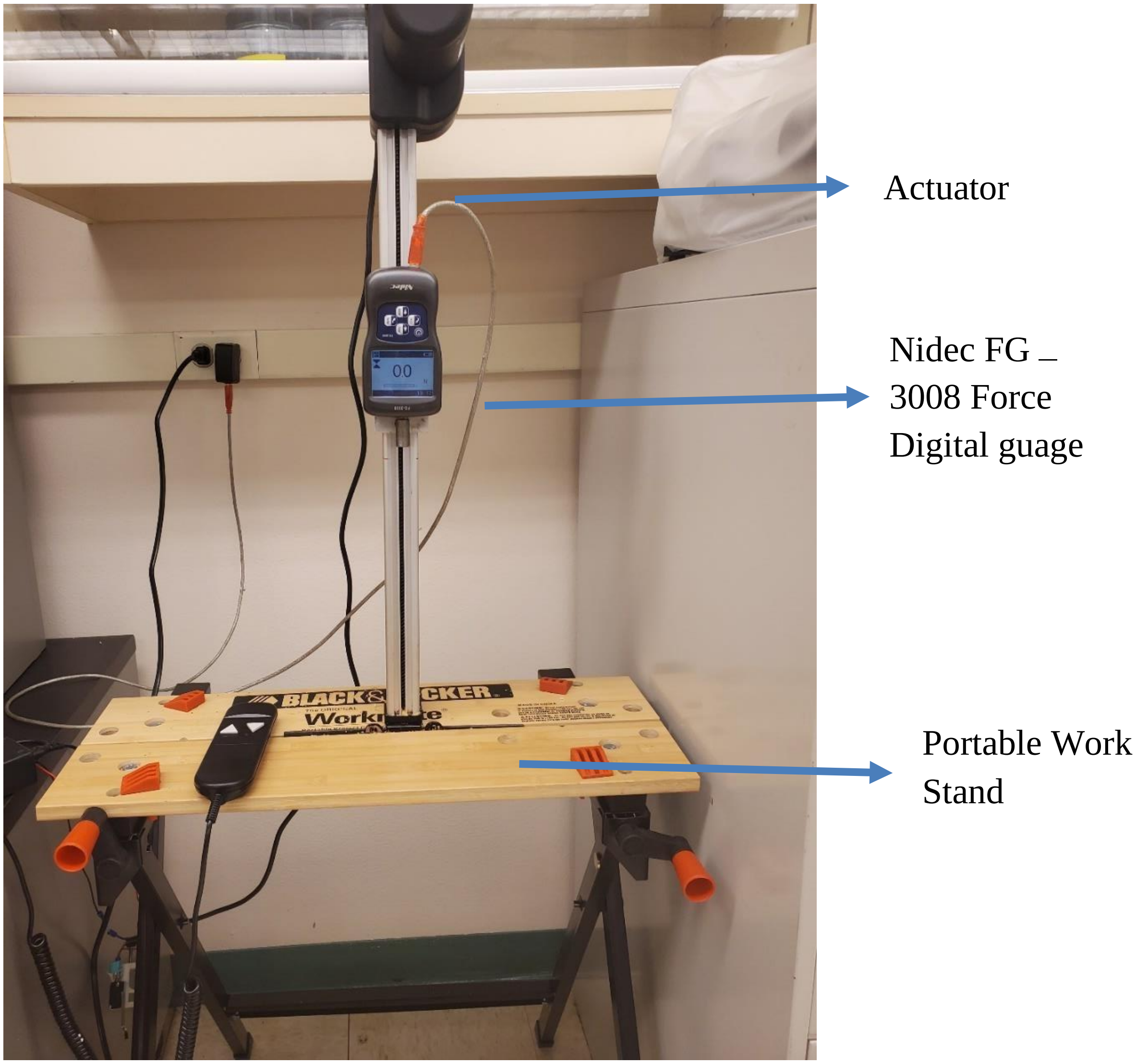
17. Process flow diagram for chemically dehaired treatment

3.7 Color

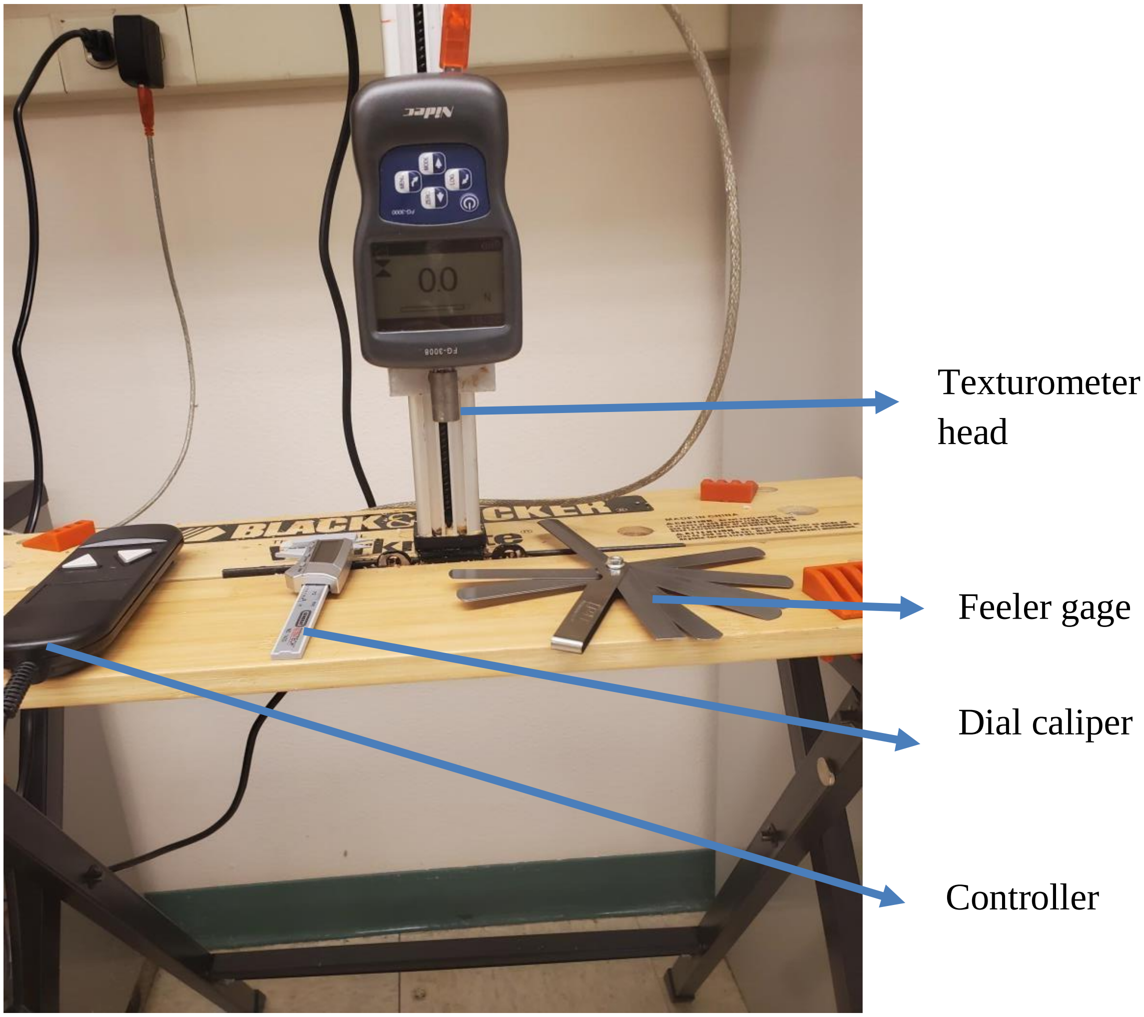
The CIE values such as L*(Level of lightness or darkness), a*(level of redness or greenness), b*(level of blueness and or yellowness) on the surface of beef skins samples were measured at three different locations using a handheld Hunters lab mini scan plus model calorimeter of serial number MO5913. (MiniScan XE Plus, Hunter Associates Lab. Inc. Reston, VA). These CIE values were used to estimate Croma and Hinge.

3.8 Texture

Texture of hide squares was measured using a texturometer device described by (Mallika et al., 2019) and shown in figure 18. The method used by (Mallika et al,. 2019) was followed with a single exception. The thickness of each hide square was measured using a dial caliper (1433 General tools and instruments, Secaucus, NJ, 07094). The zero travel distance of the contact point of the texturometer head was set at one-half the thickness of the hide sample. The zero travel distance is shown in figure 19 For example, if the hide was 20 mm thick, the zero travel distance was set at 10 mm. Zero travel distance was set using a feeler gage (W131C, Performance Tool, China) that was placed between the work table surface and the contact point of the texturometer head.



18.Low cost Texturometer



19. Texturometer set to zero travel distance

3.9 Moisture

Moisture analysis was done for hair-on, skinner, trimmer, and chemically dehaired phase samples by following the (George W Latimer et al., 2019)

2 grams of each sample was dried at 4.4^{0}C (40^{0}F) for 24 hours using a (GO1350A model, Lindberg/ blue, Asheville, NC, USA) gravity oven (Robert L et al., 2010) and, the final weights were collected for each sample to analyze the moisture content as follows:

Percentage moisture (wt / wt) = [(B – C) / (B – A)] ×100.

A = Weight of the empty pan in grams.

B = weight of the pan and weight of the sample in grams.

C = weight of the pan also with the weight of the dried sample in grams.

B – A = Weight of the sample in grams.

B – C = Final weight after drying in grams.

3.10 Hedonic scale sensory evaluation

Four sample acceptance tests were performed to decide how much expert panelists prefer the product, which will help research and develop the Ponmo (edible beef skin). A survey was conducted basing on a nine-point hedonic scale as portrayed by

(Peryam et al., 1957) as mentioned below,

(1) - Dislike extremely.

(2) - Dislike very much.

(3) - Dislike moderately.

(4) - Dislike slightly.

(5) - Neither like nor dislike.

(6) - like slightly.

(7) - Like moderately.

(8) - Like very much.

(9) - like extremely.

The expert panelist examined a comparison between the mechanical, trimmed, skinned, and chemically dehaired samples to evaluate the quality parameters, including general appearance, golden color, and hardness (texture).

3.10.1 Procedure

Three – expert panelists who process edible beef skin (Ponmo) daily at Robert M. Kerr Food and Agriculture Product Center at Oklahoma State University were requested to participate in Hedonic scale sensory analysis. Seven samples processed from each technique, such as hair-on, trimmer, skinner, and chemical dehaired, were presented to the expert panelists. A hedonic scale sheet (1 to 9) was handed to each panelist. Three questionnaires such as,

1. Which samples have the best texture (Hardness)?
2. Which samples have the best golden-brown color?
3. Which samples do you prefer based on general appearance?

They were interviewed one on one basis and requested to fill out their preference on a scale of 1 to 9. The presented samples were shown in Appendix C.

3.11 Statistical analysis:

The difference in CIE hunters calorimeter L*, a*, b* between all the developed treatments was analyzed using one-way analysis by JMP® Pro version 14.0 software

(SAS Institute, Cary, NC, 1989 – 2019). Means and standard deviations were reported. The relation between equipment data & hedonic scale sensory analysis data for color, texture and the data for moisture, weights, scorching time vs temperature were analyzed using Microsoft Excel 2013 (Microsoft, Redmond, Washington). Means, standard deviations, minimum & maximum values were reported.

CHAPTER IV

RESULTS AND DISCUSSION

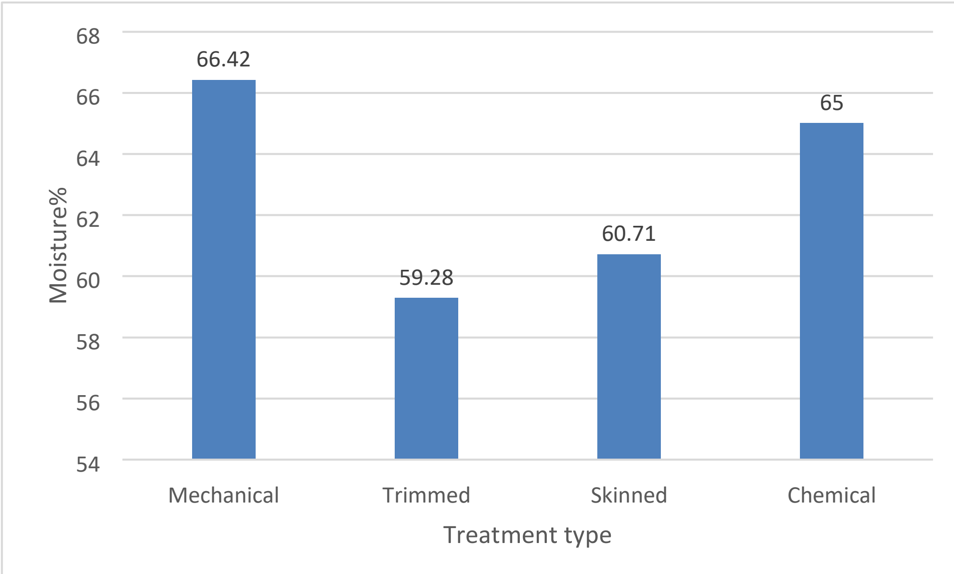
4.1 Introduction

In this chapter, firstly, I will provide details about the moisture percentage and how it is related to yield percentage. Then I will discuss the results for Hunter L*, a*, b* values for all developed treatments, and I will compare the hedonic scale values to CIE L*, a*, b* values to see if there is any relation. Secondly, I will discuss the results for texture, and then I will compare the results with hedonic scale data to see if there is any significance. Finally, I will talk about the time required to scorch the sample for each treatment using steel plate heating.

4.2 Moisture content

The moisture contents of the treatments were 66.4% for mechanically dehaired, 59.3% for trimmed hair, 60.7% for the skinned sample, and 65.0% for chemically treated sample (see figure 20). The mechanically dehaired samples has a higher moisture content (%) when compared with samples that were trimmed, skinned, and chemically treated. The higher moisture content is a result of soaking the skins in water during the preparation of Ponmo. Higher moisture content resulted in increased final yields (see figure 21).

There is a significant positive relationship between the moisture content of the mechanically dehaired treatment and chemically dehaired treatment of Ponmo, r (5) = 0.07, ($P < 0.05$). The moisture content is significantly different (see table 2). There is no significant relationship between the moisture of mechanically dehaired and skinned, trimmed treatments.



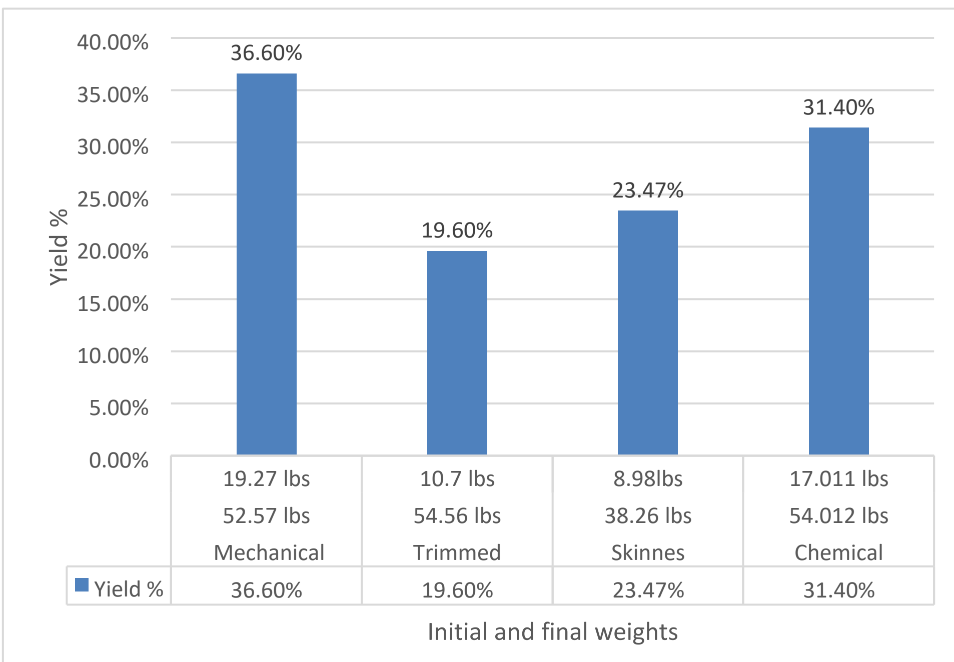
20. Moisture (%) graph for mechanical, skinned, trimmed, and chemically dehaired treatments

2. Mean, standard deviation, and p-value for trimmed, skinned, and chemically dehaired treatments.

Treatment type	**Trimmed**	**Skinned**	**Chemical**
Mean	65	60.71	65
SD	2.37	3.19	2.67
p-value	0.7	0.83	0.07
Number of samples	7	7	7

4.3 Yield (%)

The final yield percentages of mechanically dehaired, skinned, trimmed and chemically dehaired samples are shown below (see figure 21). The initial weights and final weights of each sample during the experimentation were recoded. High yield percentage of mechanically dehaired treatment was observed possibly because the Mechanical treatment is not subjected to any dehairing treatments. Lower values of yield% was observed in trimmed treatment because of taking off the top layer of the hide during dehairing process.

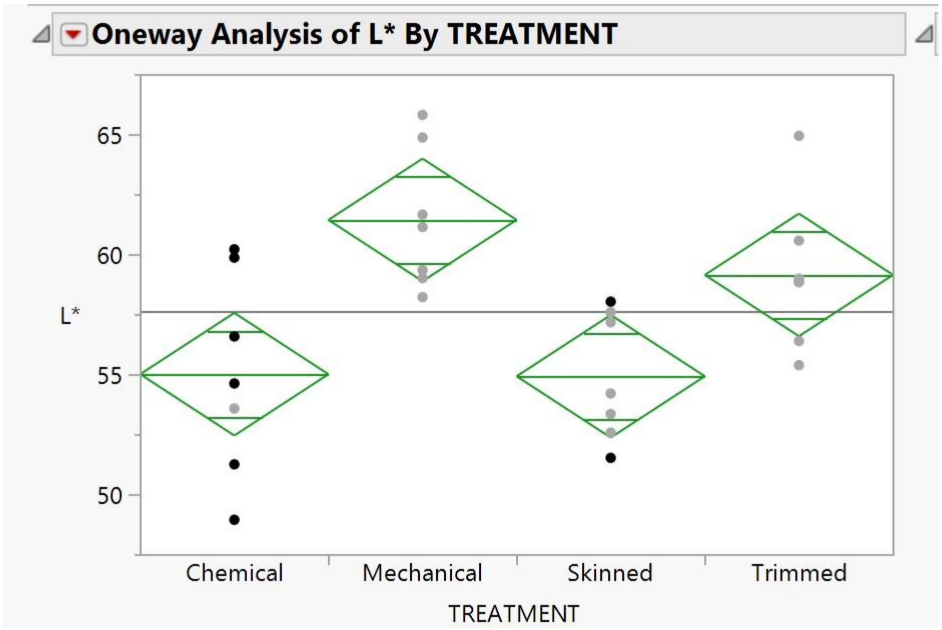


21. % yield of mechanical, skinned, trimmed, and chemically dehaired treatments

4.4 Color:

The more excellent L*value (level of lightness or darkness) were observed in the mechanically dehaired samples compared to the skinned, trimmed, and chemical samples, possibly due to more water content. A study of beef strip loins by (Rahman, 2007) showed high values of L* because of higher water content, which increased light reflectance. There was no significant relationship ($P > 0.05$) between L* values and all treatments (see table 3).

On the other hand, the chemically dehaired samples had a higher a* values (level of redness or greenness) compared to mechanical, skinned and trimmed treatments, possibly due to the addition of hydrogen peroxide on the beef hide square during the dehairing process. A study by Lu, Kun-Tsung (2006), observed redness and greenness on bamboo sticks when treated with alkaline hydrogen peroxide. There was a significant positive relationship ($P < 0.05$) that existed between the a* values (level of redness or greenness) between the treatments (see table 4). Similarly, the chemically de-haired samples have higher b* values (level of blueness or yellowness) when compared to all treatments. However, there was no significant relationship ($P > 0.05$) between b* values and all treatments (see table 5).



22. One-way Anova analysis of L* values for mechanical, skinned, trimmed, and chemical treatments

3. One-way analysis data for L* by treatment

Oneway Anova

Summary of Fit

Rsquare	0.457513
Adj Rsquare	0.389702
Root Mean Square Error	3.27438
Mean of Response	57.63835
Observations (or Sum Wgts)	28

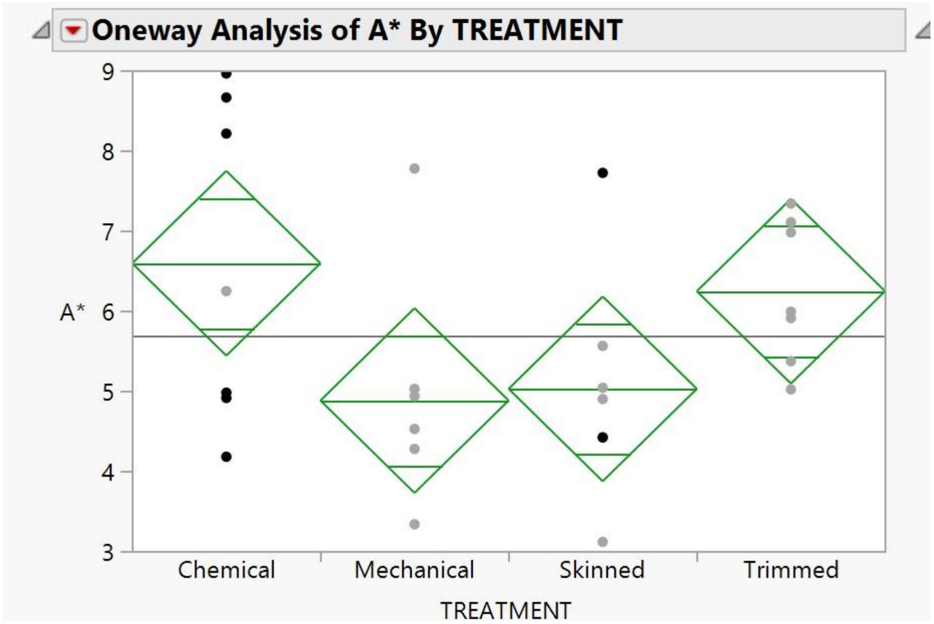
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
TREATMENT	3	217.01211	72.3374	6.7469	0.0018*
Error	24	257.31754	10.7216		
C. Total	27	474.32965			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Chemical	7	55.0183	1.2376	52.464	57.573
Mechanical	7	61.4471	1.2376	58.893	64.001
Skinned	7	54.9317	1.2376	52.377	57.486
Trimmed	7	59.1563	1.2376	56.602	61.711

Std Error uses a pooled estimate of error variance



23. One-way Anova analysis of a* values for mechanical, skinned, trimmed, and chemical treatments

4. One-way analysis data of a* for all developed treatments

Oneway Anova

Summary of Fit

Rsquare	0.228711
Adj Rsquare	0.1323
Root Mean Square Error	1.477595
Mean of Response	5.690104
Observations (or Sum Wgts)	28

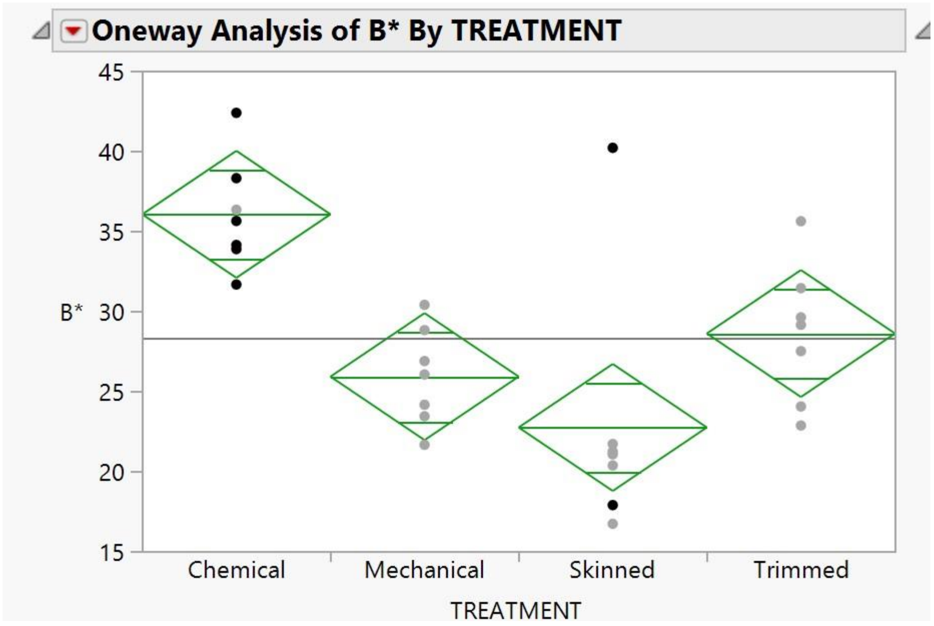
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
TREATMENT	3	15.537872	5.17929	2.3722	0.0955
Error	24	52.398912	2.18329		
C. Total	27	67.936783			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Chemical	7	6.59714	0.55848	5.4445	7.7498
Mechanical	7	4.88429	0.55848	3.7316	6.0369
Skinned	7	5.03019	0.55848	3.8775	6.1828
Trimmed	7	6.24880	0.55848	5.0962	7.4014

Std Error uses a pooled estimate of error variance



24. One-way Anova analysis of b* values for mechanical, skinned, trimmed, and chemical treatments

5. One-way analysis data of b* for all developed treatments

Oneway Anova

Summary of Fit

Rsquare	0.522159
Adj Rsquare	0.462429
Root Mean Square Error	5.082237
Mean of Response	28.34001
Observations (or Sum Wgts)	28

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
TREATMENT	3	677.3921	225.797	8.7420	0.0004*
Error	24	619.8991	25.829		
C. Total	27	1297.2912			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Chemical	7	36.0629	1.9209	32.098	40.027
Mechanical	7	25.9271	1.9209	21.963	29.892
Skinned	7	22.7518	1.9209	18.787	26.716
Trimmed	7	28.6183	1.9209	24.654	32.583

Std Error uses a pooled estimate of error variance

4.4.1 Hedonic scale

An expert sensory panel evaluated the edible beef hide products on a hedonic scale. The panel consisted of three experts that manufacture Ponmo. The experts were asked to select the sample with the best general appearance and the one with the best golden-color. Chemically dehaired samples scored highest at 8 for both golden color and general appearance (See table 6) when compared to skinned, trimmed, and mechanical samples. The large Hue angle value was observed in chemically dehaired samples when compared to all development treatments.

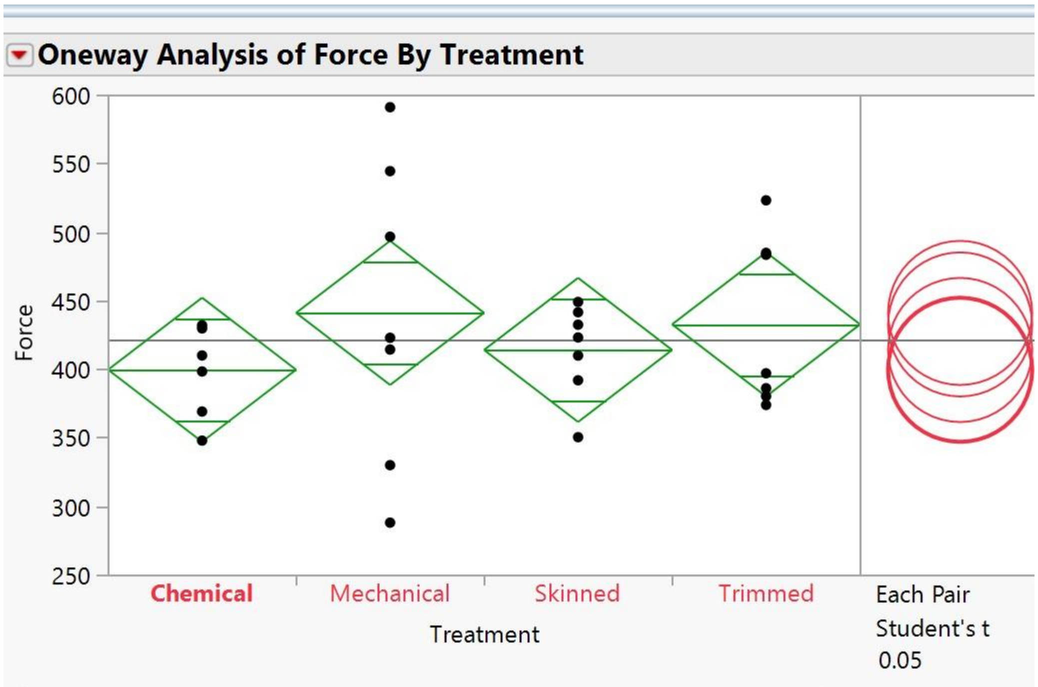
6. Hedonic scale results for golden color, general appearance and hue angle

Treatment type	**Hedonic (General appearance)**	**Golden color**	**Hue angle H***
Mechanical	7	7	1.386
Trimmed	6	7	1.352
Skinned	6	6	1.346
Chemically dehaired	8	8	1.391

4.5 Texture

The hardness (in Newton's) of hair-on, trimmer, skinner, and chemical dehairing treatments were analyzed using one-way ANOVA (see figure 25). There was a significant difference ($P < 0.05$) between all treatments. The high hardness values were observed in mechanical treatment, typically because of scorching the hide samples without any treatment. Lower hardness values were observed for the skinned and chemically dehaired samples.

Each treatment's mean texture value was compared using the student t-test LSD method (See table 8). The means of mechanical, trimmed, skinned, and chemically dehaired samples are significantly different ($P<0.05$). The means, standard deviation minimum value, maximum value, range of each treatment are reported in table 9.



25. One-way analysis for mechanical, chemical, trimmed, and skinned force data

7. One way analysis data for all developed treatments

Oneway Anova

Summary of Fit

Rsquare	0.062799
Adj Rsquare	-0.05435
Root Mean Square Error	67.35
Mean of Response	422.0293
Observations (or Sum Wgts)	28

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Treatment	3	7294.65	2431.55	0.5361	0.6621
Error	24	108864.54	4536.02		
C. Total	27	116159.19			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Chemical	7	399.786	25.456	347.25	452.32
Mechanical	7	441.243	25.456	388.70	493.78
Skinned	7	414.229	25.456	361.69	466.77
Trimmed	7	432.860	25.456	380.32	485.40

Std Error uses a pooled estimate of error variance

8. Results of Comparisons of all developed treatments mean between all treatments

Means Comparisons

Comparisons for each pair using Student's t

Confidence Quantile

t	Alpha
2.06390	0.05

LSD Threshold Matrix

Abs(Dif)-LSD

	Mechanical	Trimmed	Skinned	Chemical
Mechanical	-74.301	-65.918	-47.286	-32.843
Trimmed	-65.918	-74.301	-55.669	-41.226
Skinned	-47.286	-55.669	-74.301	-59.858
Chemical	-32.843	-41.226	-59.858	-74.301

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level		Mean
Mechanical	A	441.24286
Trimmed	A	432.86000
Skinned	A	414.22857
Chemical	A	399.78571

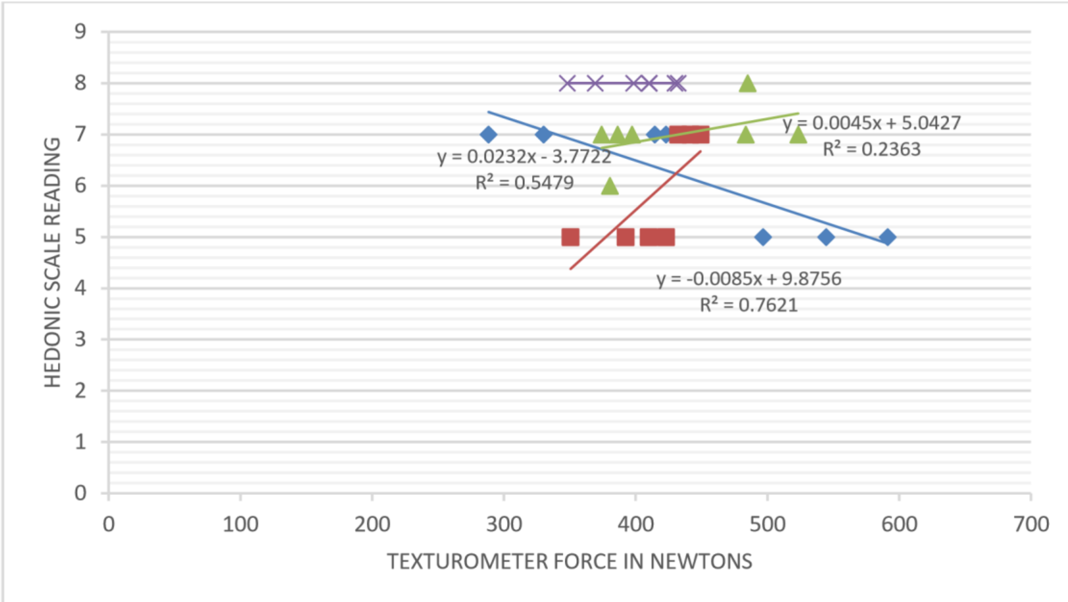
Levels not connected by same letter are significantly different.

9. Hardness data mean, standard deviation, maximum, minimum, range of mechanical, skinned, trimmed, and chemically dehaired treatments

Treatment	**Mechanical**	**Skinned**	**Trimmed**	**Chemical**
Number of samples	7	7	7	7
Mean	441.24	414.22	432.86	399.7
Standarddeviation	102.13	31.51	57.45	28.73
Minimum value	591.2	449.2	523.32	432.2
Maximum value	288.3	350.6	374.1	348.1
range	302.9	98.6	149.22	84.1

4.5.1 Hedonic Scale vs Texturometer

The expert sensory panel evaluated the hardness of the samples on the 1 to 9 hedonic scale. A high score of 8 out of 9 was observed for the chemically dehaired samples. The mechanical, skinned, and trimmed samples had mean values of 6.1, 5.9, and 7.0, respectively (see table 10). There was no significant relationship between the data measured with the texturometer and the results of sample hardness assessed by the sensory panel (see picture 26).



26. XY scatterplot for texturometer hardness vs hedonic scale hardness

10. Mean and standard deviation for hedonic scale hardness for hair-on, trimmer, skinner, and chemical

Treatment	**Mechanical**	**Trimmer**	**Skinner**	**chemical**
Mean	6.142	7	5.857	8
Standard deviation	0.98	0.53	0.98	0
N	7	7	7	7

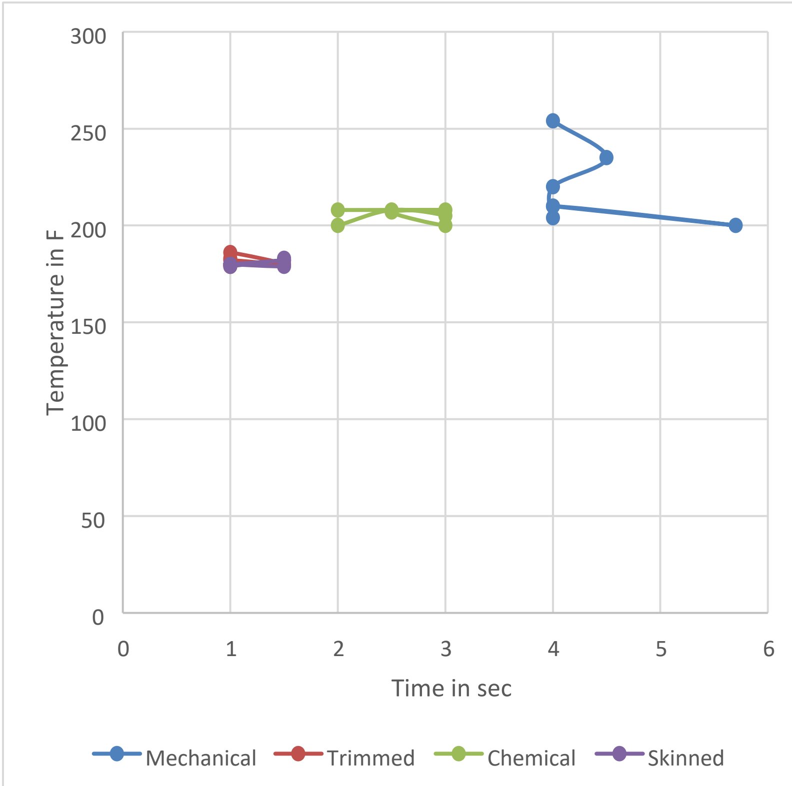
4.6 Temperature vs. Scorching time

The temperature and time were recorded during scorching the hide squares at 704.4^{0}C for each treatment. Means and standard deviations for time and temperature are tabulated below (see table 11). Mechanical treatment took 4 minutes 31seconds at 103^{0}C. Longer duration and high temperature for hair-on treatment were observed possibly because the mechanical treatment is not subjected to any dehairing treatments. The trimmed and skinned treatments took less time to scorch at a temperature of 82.7^{0}C (181^{0}F) and 82.2^{0}C (180^{0}F). Less time and low temperatures for skinned and trimmed treatments were observed (see figure 27) compared to mechanical treatment, possibly taking off the hair in both treatment procedures. The chemical treatments also show less significant time of

2.57 seconds and temperatures of 96^{0}C when compared to mechanical treatment.

11. Mean, standard deviation of time and temperatures for scorching time and hide temperature after scorching for mechanical, trimmed, chemical, and skinned treatments

Treatment	**Mechanical**	**Trimmed**	**Skinned**	**Chemical**
Meantime	4.31 sec	1.071sec	1.28 sec	2.57 sec
Mean temperature	(103.8^{0}C) 219^{0}F	(82.7^{0}C) 181.4^{0}F	82.2^{0}C (180.7^{0}F)	96.1^{0}C (205.14^{0}F)
Standard deviation time	0.59	0.174	0.24	0.41
Standard deviation temperature	17.84	2.258	1.48	3.39



27. Time vs. temperature XY scatter plot for mechanical, trimmed, chemical, and skinned treatments.

CHAPTER V

CONCLUSIONS

This study focused on methods and parameters that are important in the manufacturing process of Ponmo (edible beef skin). Treatments included different dehairing techniques (mechanical, trimmed, skinned, chemical) and scorching the hides using steel plates, followed by analyzing quality parameters such as color, texture and moisture. An expert sensory panel evaluated the different treatments to investigate differences in color and texture. Conclusions can be drawn as follows.

1. The moisture content of hair-on samples was observed to be the highest of all the treatments, which results in a high yield. The skinner and trimmer have significantly lower moisture contents compared to the mechanical, which would result in a lower yield.

2. The more excellent L* values were observed from mechanical samples, but there was no significant relationship between the treatments ($P > 0.05$). High a* values were observed in chemically dehaired samples. However, there was a significant relationship between the treatments ($P < 0.05$). High b* values were observed in chemically dehaired samples, and there was no significant positive relationship between the treatments.

3. There was no significant positive correlation between Hunter's L*, a*, b* values compared with results from the expert sensory panel for general appearance and golden color ($P>0.05$).

4. Mechanical, trimmed, skinned, and chemically dehaired samples hardness values were significantly different ($P < 0.05$).

5. A significant difference existed between the hardness measurement using a texturometer for the skinned, trimmed, mechanical, and chemical dehaired samples. The mechanical treatment samples have a higher hardness than other treatments. The means of all treatments were compared, and they were significantly different ($P<0.05$).

6. The highest scorching temperature and longest scorching time were observed for the mechanical treatments. Shorter duration and lower scorching temperatures were observed for the trimmed, skinned, and chemically dehaired treatments when compared to the mechanical treatment.

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APPENDICES

APPENDIX A

Data for manufacturing Ponmo using traditional methods

Kanda pomo data collection

Day-1,2				Date:06-08-2020, 06-09-2020
Hide Condition: Dry				
	Breed of the animal: Hereford, Angus			
Age of animal : 1. 30+ ,2. 30-				
	Electric count: NA			
Initial gas count: 06979 cu f		Propane Gas: 2.2+60Lbs		Initial Time1: 8:25AM
				Initial time2: 8:40AM
Final Gas count : 07013 cu f				
Raw hide weight: 390.95 lb		Temperature: 66F,67F,66F		
			Number of workers: 05	Break1- 12:00PM -1:00PM
After Seinging: 206.3 lb		Temperature: 157F, 174F, 160F		Break2 - 12:30PM - 1:15PM
			Number of workers: 05	
Water CCP: below 50F		Temperature: 72F, 39F,41F,32F		Final Time1: 4:00Pm
				Final time2: 3:00Pm
Day-3				Date:06-10-2020
Time of soaking: 40 Hr+16Hr				
		Temperatureof room: 32F-35F	Number of workers: 05	InitialTime: 8:30AM
Weight after cleaning: 317 Lbs				
Type of packing material: Plastics				
Water usage: 122.1Gallons				
			Number of workers: 05	Final Time: 5:00PM
Weight after packaging: 320 lb				
Quality	Color: Acceptable	Texture: N/a	Moisture Content:N/A	
Total:	Gas Count	Electric Usage	Water Usage	Total Time
	Natural: 34cu f	NA	For Processing: 152.1 Gallons	For singeing 1: 6hours 30 minutes
	Propane: 62.2 Lbs			For Singeing 2: 5 hours 30 minutes
				For Scraping: seven hours

APPENDIX B

Data for plate scorching experiment at different temperatures

Data and pictures for hot plate scorching experiment:

Table 1

Time taken by the hot plates to reach target temperatures.

700^{0}F(371.11^{0}C)	1000^{0}F(537.77^{0}C)	1300^{0}F(704.44^{0}C)
1. 9 Minutes 44 seconds	1. 13 minutes	1. 16minutes
2. 9 minutes	2. 13minutes56 seconds	2. 15 minutes

Table 2

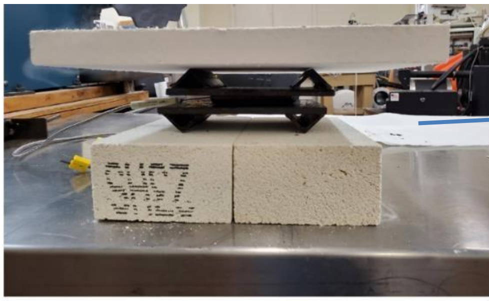
Weights

Sample code	Initial weight	Final weight
HoN01	59.93g	35.69g
HoN02	58.02g	49.09g
HoN03	57.56g	23.82g
HoN04	57.58g	23.0g
HoN05	56.28g	27.27g
HoN06	57.57g	29.08g

Table 3

Time is taken for scorching and final hide temperature:

Sample code	Scorching time	Hide temperature(Initial)	Hide temperature After scorching	Temperatures
HoN01	7minutes 54seaconds	20^{0}C	180.2^{0}C	700^{0}F
HoN02	8 minutes 02 seconds	21.33^{0}C	178.23^{0}C	700^{0}F
HoN03	7 minutes	23.33^{0}C	246.2^{0}C	1000^{0}F
HoN04	6 minutes	21.0^{0}C	245.9^{0}C	1000^{0}F
HoN05	5 minutes	19.0^{0}C	332.2^{0}C	1300^{0}F
HoN06	4 minutes	19.65^{0}C	330.01^{0}C	1300^{0}F



Picture 1: Experiment set up

Steel plate scorching

Picture 2: Hide squares after scorching and scraping.

Rawhide squares scorched at 371.11C, 537.7C, 704.4C

Sample scorched at 704.4C

Sample scorched at 371.11C.

Sample scorched at 537.7C

APPENDIX C

Processed Ponmo pictures for developed treatments:

Mechanical:

Processed hide squares for Mechanical treatment.

Trimmed:

Rawhide squares after trimming the hair with Trimmer

Processed Ponmo for Trimmed treatment

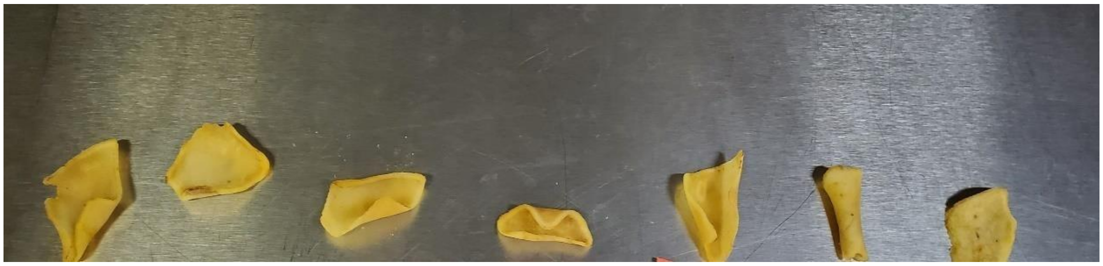
Skinned:

Raw skins after skinning with skinner equipment

Processed ponmo squares for Skinner treatment

Chemical

Raw hides after deharing with sodium hydroxide and hydrogen peroxide



Processed Ponmo Squares for Chemical deharing treatment

VITA

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