UNIVERSITI PUTRA MALAYSIA

QUALITY CHARACTERISTICS OF BEEF PATTIES INFLUENCED BY DIFFERENT VARITIES OF PEEL POWDERS

ADIBAH ZAHIAH AZHAR

QUALITY CHARACTERISTICS OF BEEF PATTIES INFLUENCED BY DIFFERENT VARIETIES OF PEEL POWDERS

ADIBAH ZAHIAH BINTI AZHAR

192335

PROJECT REPORT SUBMITTED IN PARTIALLY FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF ENGINEERING PROCESS AND FOOD WITH HONOURS

DEPARTMENT OF PROCESS AND FOOD ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITI PUTRA MALAYSIA

2021

ACKNOWLEDGEMENT

First and foremost, I would want to thank the Almighty God for providing me with the strength, patience, and knowledge that enabled me to accomplish this final year project efficiently and successfully.

My heartfelt gratitude goes to Puan Zanariah bt Mohd Dom, my delightful, ever supportive, and modest supervisor, for her many and essential contributions and directions during my studies. I have really benefited from your breadth of expertise and meticulous guidance. I am profoundly grateful that you accepted me as a student and genuinely believed in me throughout the years.

I would like to convey my sincere appreciation thanks to my examiners, Dr. Nor Amaiza Mohd Amin and Dr. Nur' Aliaa Abdul Rahman for their wise advice, constructive comments, ideas, support, and inspiration during this effort. I am forever indebted to laboratory assistants. Their unwavering support helped me to complete this piece.

The days would have passed much more slowly without the support of my friends. I cannot forget friends who went through hard times together, cheered me on, and celebrated each accomplishment. I promise that I would always keep those sweetest memories safely in my mind.

Thank you to my parents and family for their everlasting support. You've always stood by my side, and this was no exception. Umi and Abah, thank you for all your love and for constantly reminding me of the end goal. It was their love that raised me again when I got weary. May Allah bless each of you every day, Aamin.

ABSTRACT

Fruit peels are rich in bioactive compounds that can be utilized as antioxidants and nutraceuticals in providing an excellent alternative to synthetic antioxidants in meat products, especially in combating meat's oxidative reactions caused by the breakdown of lipids and proteins. Therefore, this study was conducted to develop beef patties by incorporating banana, pomegranate, and orange peel powders to improve nutritional, physicochemical, cooking properties, bacteria quality, color, texture, and sensory aspects. The meat samples are mixed with different types of fruit peel powders (banana peel powders (BPP), pomegranate peel powders (PPP) and orange peel powders (OPP)) at different concentrations (1, 2, 3%), besides the control untreated formula. An increase in ash, fat and fiber and a decrease in moisture and protein was achieved with an increasing concentration of peel powders. The addition of 3% OPP and PPP to the beef patties caused the highest reduction in total volatile basic nitrogen (TVBN) and pH value. Superior cooking properties, as well as water (WHC) and oil holding capacity (OHC), were improved significantly *($p<0.05$)*. BPP and PPP affected the color by lowering *($p<0.05$)* L*, a*, and b* values while OPP showed the opposite trend. Somewhat increase *($p<0.05$)* in hardness, gumminess, and chewiness with an increasing percentage of peel powders while non-significant *($p>0.05$)* decrease in springiness and cohesiveness were noticed. Incorporation of 1% of any type of fruit peel powder into the beef patties yielded high scores of sensory evaluations and overall acceptability, which were almost the same as control scores. Thus, the food sector may employ these peel powders as a natural source of antioxidants, antimicrobial, and health-promoting functional ingredients, as well as a substitute for synthetic antioxidants like butylated hydroxytoluene (BHT).

ABSTRAK

Kulit buah kaya dengan bahan kimia bioaktif yang dapat digunakan sebagai antioksidan dan nutraseutikal dalam menyediakan alternatif antioksidan sintetik yang sangat baik dalam produk daging terutama dalam memerangi reaksi oksidatif daging yang disebabkan oleh pemecahan lipid dan protein. Oleh itu, kajian ini dilakukan untuk mengolah roti burger daging lembu dengan memasukkan serbuk kulit pisang, serbuk kulit delima, dan serbuk kulit oren untuk meningkatkan aspek pemakanan, fizikokimia, sifat memasak, kualiti bakteria, warna, tekstur dan deria. Sampel daging dicampur dengan pelbagai jenis serbuk kulit buah (serbuk kulit pisang (BPP), serbuk kulit buah delima (PPP) dan serbuk kulit oren (OPP)) pada kepekatan yang berbeza (1, 2, 3%), selain kontrol yang tidak dirawat formula. Peningkatan abu, lemak dan serat serta penurunan kelembapan dan protein dicapai dengan peningkatan kepekatan serbuk kulit. Penambahan OPP dan PPP sebanyak 3% pada roti burger daging lembu menyebabkan penurunan tertinggi dalam jumlah nitrogen asas tidak stabil (TVBN) dan nilai pH. Sifat memasak yang unggul, serta air (WHC) dan daya tahan minyak (OHC), meningkat dengan ketara *($p<0.05$)*. BPP dan PPP mempengaruhi warna dengan menurunkan *($p<0.05$)* nilai L*, a* dan b* sementara OPP menunjukkan arah aliran yang berlawanan. Sedikit peningkatan *($p<0.05$)* dalam kekerasan, kelekitan dan kekenyalan dengan peningkatan peratusan serbuk kulit sementara penurunan yang tidak ketara *($p>0.05$)* pada keanjalan dan kekompakan diperhatikan. Penggabungan 1% sebarang jenis serbuk kulit buah ke dalam roti burger daging lembu menghasilkan penilaian sensori yang tinggi dan penerimaan keseluruhan yang hampir sama dengan skor kawalan. Oleh itu, sektor makanan boleh menggunakan serbuk kulit ini sebagai sumber semula jadi antioksidan, antimikrobial, dan

bahan-bahan fungsional yang mempromosikan kesihatan, dan juga sebagai pengganti antioksidan sintetik seperti butilasi hidroksitoluena (BHT).

TABLE OF CONTENTS

APPROVAL....... ii

DECLARATION iii

ACKNOWLEDGEMENT iv

ABSTRACT v

ABSTRAK vi

TABLE OF CONTENTS viii

LIST OF TABLES xii

LIST OF FIGURES xii

LIST OF ABBREVIATIONS xiv

CHAPTER 1 INTRODUCTION 1

1.1 Background 1

1.2 Problem Statement 4

1.3 Objectives 5

1.4 Scope of Study 6

CHAPTER 2 LITERATURE REVIEW 7

2.1 Overview 7

2.2 Orange (Citrus Sinensis L.) Peels 8

2.3 Pomegranate (Punica Granatum L.) Peels 9

2.4 Banana (Musa Paradisicum) Peels 11

2.5 Effect of fruit peels addition on chemical compositions of meat-based products 12

2.6 Effect of fruit peels addition on pH and TVBN values of meat-based products 15

2.7 Effect of fruit peels addition on water holding capacity (WHC) and oil holding capacity (OHC) of meat-based products 18

2.8 Effect of fruit peels addition on cooking properties of meat-based products 20

2.9 Effect of fruit peels addition on color evaluation of meat-based products 22

2.10 Effect of fruit peel addition on texture profile analysis of meat-based products 24

CHAPTER 3 METHODOLOGY 26

3.1 Material and methods....26
3.1.1 Preparation of dried fruit peels 26
3.1.2 Preparation of beef patties 26
3.2 Chemical analysis of beef patties....30
3.2.1 Proximate composition analysis 30
3.3 Physicochemical quality criteria of prepared beef patties 32
3.3.1 pH value measurement.... 32
3.3.2 Total Volatile Basic Nitrogen (TVBN).... 32
3.3.3 Water Holding Capacity (WHC) and Oil Holding Capacity (OHC).... 33
3.4 Technology and qualities analysis 34
3.4.1 Cooking properties.... 34
3.4.2 Color analysis 34
3.4.3 Texture profile analysis.... 36
3.5 Sensory evaluation 36
3.6 Statistical analysis....36
CHAPTER 4 RESULTS AND DISCUSSION 37
4.1 Proximate analysis of beef patties with different percentages of peel powder 37
4.2 Physicochemical analysis 42
4.2.1 pH analysis 42
4.2.2 Total Volatile Basic Nitrogen (TVBN) analysis.... 45
4.2.3 Water Holding Capacity (WHC) and Oil Holding Capacity (OHC).... 46
4.3 Technology and quality analysis....51
4.3.1 Cooking properties.... 51

4.3.2 Color analysis 55
4.3.3 Texture analysis 60
4.4 Sensory evaluation 67
CHAPTER 5 CONCLUSION AND RECOMMENDATION 72
5.1 Conclusion 72
5.2 Recommendations 74
REFERENCES 75
APPENDICES 93
5.3 pH analysis 93
5.4 Cooking properties 94
5.5 WHC and OHC analysis 96
5.6 Color analysis 97
5.7 Texture Analysis 99
5.8 Sensory Evaluation 101

LIST OF TABLES

Table 3.1 Formulation in beef patties 28

Table 4.1 Proximate composition of raw beef patties at different concentrations of banana, pomegranate, and orange peel powders 37

Table 4.2 pH values of raw beef patties at different concentrations of banana, pomegranate, and orange peel powders 42

Table 4.3 TVBN of raw beef patties at different concentrations of banana, pomegranate, and orange peel powders 45

Table 4.5 WHC and OHC of raw beef patties at different concentrations of banana, pomegranate, and orange peel powders 46

Table 4.4 Cooking properties of beef patties at different concentrations of banana, pomegranate, and orange peel powders 51

Table 4.6 Color analysis of cooked beef patties at different concentrations of banana, pomegranate, and orange peel powders 55

Table 4.7 Texture profile analysis of cooked beef patties at different concentrations of banana, pomegranate, and orange peel powders..60

Table 4.8 Sensory evaluation of cooked beef patties at different concentration of banana, pomegranate, and orange peel powders 67

LIST OF FIGURES

Figure 2.1 Orange *(Citrus × sinensis)*. Adopted from (Tighe-Neira et al., 2017) 9

Figure 2.2 Pomegranate *(Punica granatum L.)*. Adopted from (Gabriele, 2014) 10

Figure 2.3 Banana *(Musa Paradisicum)*. Adopted from (Amazing Fact, 2017)..12

Figure 2.4 pH scales. Adopted from (Rufenacht, 2020) 16

Figure 2.5 CIELAB Color Space. Adopted from (Cubillas & Japitana, 2016) ...23

Figure 3.1 Prepared beef patties with 1,2,3% of banana, pomegranate, and orange peel powders 29

Figure 4.1 Radar chart of the best percentage of fruit peel powders. 71

LIST OF ABBREVIATIONS

Abbreviation	Meaning	Page
BPP	banana peel powders	28
BPP1	1% banana peel powders	28
BPP2	2% banana peel powders	28
BPP3	3% banana peel powders	28
OHC	oil holding capacity	18
OPP	orange peel powders	28
OPP1	1% orange peel powders	28
OPP2	2% orange peel powders	28
OPP3	3% orange peel powders	28
PPP	pomegranate peel powders	28
PPP1	1% pomegranate peel powders	28
PPP2	2% pomegranate peel powders	28
PPP3	3% pomegranate peel powders	28
TVBN	total volatile basic nitrogen	15
WHC	water holding capacity	18

CHAPTER 1

INTRODUCTION

1.1 Background

Frozen meat and meat products are available for domestic and consumer use. Changes such as rising population, urbanization, economic growth and industry expansion are driving higher demand for meat products. Global per capita intake of meat (average) rose from 20 kg in 1961 to 43 kg in 2014 and now, the world currently makes over than triple even more meat as it did fifty years ago. In 2018, output was about 340 million tonnes (Ritchie & Roser, 2017). Nowadays, frozen meat product has an immense request with a high commercial value where meat and poultry are the fantastic source of protein. They also supply a lot of other nutrients that our body requires, including iodine, iron, zinc, vitamins (especially B12) and essential fatty acids (M. Ibrahim et al., 2018). However, they are considered as perishable food because they tend to spoil easily and need to be well preserved in order to keep the germs from multiplying and to stay fresh.

During long-term frozen meat storage, the most notable quality involves color degradation, fat oxidation, protein degradation, and ice crystal formation (Augusto et al., 2009). Microbial spoilage and fat rancidity are the underlying issue that affects meat products, contributing to the use of synthetic preservatives such as nitrates and nitrites that have a carcinogenic impact on the human body, compromising its wellbeing and taking it to these foods (Mahmoud et al., 2017). Oxidative reactions of meat lead to the degradation of lipids and proteins which, in turn, lead to the deterioration of the taste, texture and color of the meat products produced (Decker et al., 1995). In the other hand, processed meat products, in particular burgers containing a high percentage of fat, count as the primary cause of chronic diseases such as obesity, atherosclerosis and heart disease.

The rate and degree of oxidative degradation can be controlled by different methods, such as curing, vacuum packing, adjusted atmosphere packaging and, most notably, by the addition of synthetic or natural antioxidants (El-nashi et al., 2015). The most common preservation system for short-term storage of fresh meat and meat products is typically refrigeration storage. Antimicrobial and antioxidant additives, those of synthetic origin, are applied to meat products in order to increase the refrigerated storage period. These days, due to their possible toxicological consequences, the usage of these synthetic antioxidants has been monitored (Naveena et al., 2008). However, as the safety of synthetic additives has been debated in recent years, consumers are gradually demanding for the use of natural ingredients as substitute preservatives in food (Imaida et al., 1983). There is a greater need for the production and use of more powerful antioxidants of natural origin. Growing interest in the replacement of synthetic antioxidants by natural antioxidants has recently led to a considerable growth of research on the screening of natural antioxidants from cheap and residual agricultural sources. The use of natural antioxidants has become a recent invention of nutritious food that has a natural or "green" image. This has prompted researchers and food producers to search for natural antioxidants with a vast array of antimicrobial and antioxidant action.

Fruit and seed by-products such as peels and husks have been reported to be a great source of bioactive compounds that can be used as antioxidants and nutraceuticals (Larrauri et al., 1996; Lu & Yeap Foo, 2000; Moure et al., 2001). Indeed, these inedible parts contain bioactive compounds with higher antioxidant activity than pulp and have phytochemical profiles different from other sections of the plant (Can-cauich et al., 2017). Fruit peels may account for around 30% of the total weight of certain fruits and have greater biological activity than other parts of the fruit; nevertheless, they are gradually gaining popularity. The use of inedible portions usually requires their processing into to reduce volume by eliminating free water and reducing chemical and microbiological reactions. This makes them better to handle while at the same time increasing the concentration of bioactive chemicals, dietary fiber and minerals (Abdel-naeem & Malak, 2020; Law et al., 2009). Therefore, the idea of utilization of fruits peel into meat products can be studied especially to preserve it from deterioration and rancidity as well as to promote the highly nutritional values played by the bioactive components and another trace elements. From a good hygiene point of view, fruit peels are considered waste and are a source of environmental pollution, and the effective use of these fruit peels will enable the industry and the authority to reduce waste agribusiness and improve agricultural viability

1.2 Problem Statement

The significant moisture content, favorable water action and pH, and unsaturated fatty acid content enable the meat and its components to be very perishable and optimum for bacterial growth and lipid oxidation (Hawthorn, 1969; Vinci & Antonelli, 2002). The oxidative reactions of the meat contribute to the degradation of the lipids and proteins, leading to a deterioration of the taste, texture, color, and nutritional value of the products produced, limiting its shelf-life (Decker et al., 1995; Fernández et al., 1997). Furthermore, during the manufacture of meat products, fine grinding, air absorption, haem pigments, metal contact, and hot temperatures during processing lead to lipid oxidation that creates unpleasant consequences from a sensory point of view (Abdel-naeem & Malak, 2020). The rate and degree of oxidative deterioration can be minimized through different mechanisms such as curing, vacuum packing, changed atmosphere packaging, and, most notably, applying synthetic or natural antioxidants to prevent beef products from spoiling during production and packaging. Nevertheless, customers are now becoming more conscious of the flaws of chemical antimicrobial and antioxidant compounds and their health impact relationships that have been used to prolong the shelf life of foods (Ahmad et al., 2015).

Moreover, synthetic antioxidants have been used as antioxidants in meat and poultry products for many years, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tert-butylhydroquinone (TBHQ) and propyl gallate (PG) (Haque et al., 2020). Due to their possible toxicological consequences, the use of these synthetic antioxidants has been scrutinized in recent days (Naveena et al., 2008) and have renewed market interest in the procurement of natural ingredients in which the meat and poultry industry has been looking for natural antioxidants currently (El-nashi et al., 2015).

The disposal of by-products leads to a loss in potential revenues and a rise in the disposal cost of these products (Jayathilakan et al., 2012). Citrus fruits, for example, are widely consumed as fresh food and juice across the world, and the peel is usually thrown as wastes, giving away a broad spectrum of secondary components with considerable antioxidant activity compared to other sections of the fruit (Manthey & Grohmann, 2001). Over the past few years, global citrus fruit production has increased dramatically, exceeding 82 million tonnes in 2009-2010, of which oranges account for around 50 million tonnes, the most valuable commercial citrus fruit where 34% of this was used for the production of juice, producing approximately 44% of the peel as a by-product (Li et al., 2006). Thus, a large amount of peel is generated every year where it should be utilized instead of landing them in landfills.

1.3 Objectives

The purpose of this study was to evaluate the effect of incorporating banana, orange, and pomegranate peel powders at different concentrations on the chemical compositions, physicochemical, and sensory properties of prepared beef patties. The second objective is to assess the effect of fruit peel powders additions into beef patties on the technology and quality properties.

1.4 Scope of Study

The study was primarily focused on the evaluation of the chemical compositions, physicochemical, and sensorial properties of different fruits which are orange, pomegranate, and banana. Also, we studied about the effect of fruit peel powders additions into beef patties on the technology and quality properties which include cooking properties, WHC, OHC, color and texture. This research aimed to determine the effect of adding those fruits peel powder on preserving the quality, nutritional values, physicochemical, and safety characteristics of prepared beef patties. The expected results also will be compared with the beef patties that contains no peel powder added. This study will be conducted in two cities in Malaysia which are Serdang, Selangor and Ipoh, Perak. Next, the analysis would be done through lab experiment and through sensory evaluation.

The estimated time range of the experiment from the extraction of peelings to the outcome of the result ranges from minimum time of 2 hours until 48 hours depending on the quantity of the amount of sample used. The duration to complete the experiment was 10 weeks (approximately starting from March 2021 until May 2021). The general budget for this experiment ranges from a minimum amount of RM 500 (includes raw materials and equipment) to a maximum amount of RM 1500 which depends on the availability of the material and equipment provided.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Through incorporating beneficial health components and by eliminating or minimizing unhealthy substances, meat products may be altered into a more "healthier" form. In this way, a variety of food items can be acquired without modifying their foundation and are considered "healthy." The idea of utilizing food for health rather than nourishment may transform the entire market for the meat business (Zuhaib et al., 2013). The fundamental issue that affects meat products is microbial spoilage and lipid rancidity, which leads to synthetic preservatives, including nitrates and nitrites, which have a carcinogenic effect on the human body, putting people's wellbeing at risk by adding them to food. (Decker et al., 1995). In addition, the oxidative stability of the meat relies on the balance and association between the endogenous anti-and pro-oxidant compounds and the composition of oxidizing-prone substrates, like polyunsaturated fatty acids (PUFA), cholesterol, protein, and pigment (Devatkal et al., 2012).

Therefore, natural alternatives have been studied to replace the usage of synthetic preservatives in meat products, owing to their beneficial technological and nutritional properties that provide customers possible health security, the re-use of these wastes in an acceptable manner may be of great economic benefit to food producers, as well as minimizing the environmental effects and adding value to this residue. The properties of fruits have been due to their high content of bioactive compounds that act as antioxidants, antimicrobials, anti-mutagenic, anti-carcinogenic, colorants, flavorings and thickeners

(El-khalek & Zahran, 2013; Parashar et al., 2014). Furthermore, because of their high phenolic component concentration, fruits, vegetables, and other plant materials are a viable alternative to traditional natural antioxidants and can serve as a source of antioxidant chemicals for meat products. (El-nashi et al., 2015). This study will focus on the potential of orange, pomegranate, and banana fruit peel as natural preservatives.

2.2 Orange (Citrus Sinensis L.) Peels

Orange *(Citrus sinensis L.),* a hesperidium of the Rutaceae family, is the most commonly cultivated and commercialized citrus species (Haque et al., 2020). There is a potential in the production and use of 'citrus waste' including lemon *(Citrus × limon)* and orange *(Citrus × sinensis)* peels as usable antioxidant and antimicrobial additives through the manufacturing of organic meat products to improve oxidative stability and sustain the consistency of meat for longer lifespan, while ensuring consumer food welfare and demand for natural and secure products (M. Ibrahim et al., 2018). Citrus fruits and their by-products are very prominent in both developed and developing countries due to their favored aroma, delicious taste, inexpensive economic scope and consumer awareness of increasingly recognized potential safety and health properties (Haque et al., 2020). Citrus waste is of enormous value as it provides a high quantity of various flavonoids, carotenoids, dietary fiber, fats, polyphenols, essential oils, ascorbic acid, as well as trace elements (K. Sharma et al., 2017). Apart from sugars, acids and polysaccharides, oranges are essential for phytochemicals, such as phenols, ascorbic acids and carotenoids (Haque et al., 2020). These substances, also known as nutraceuticals, deliver health benefits that prevent infectious diseases such as cancer and cardiovascular disease (Haque et al., 2020). However, lemon and orange peels are known to be main by-products of citrus and discarded as waste. The re-use of these by-products in an acceptable form can be of significant economic benefit to food processors due to their beneficial technical and nutritional, which offer potential consumer health protection as well as mitigating environmental impact, adding value to these residues, and increase the industrial profitability (Ayala-Zavala & González-Aguilar, 2010).

Figure 2.1 Orange *(Citrus × sinensis)*. Adopted from (Tighe-Neira et al., 2017)

2.3 Pomegranate (Punica Granatum L.) Peels

Pomegranate *(Punica granatum L.)* peels generate many natural antioxidants and are an essential source of tannins, anthocyanins, and flavonoids (Naveena et al., 2008). Lately, dietary flavonoids are regarded as more effective antioxidants among natural antioxidants and have received growing attention as a potential defender against various human diseases, especially cardiovascular diseases and cancer (Ren et al., 2003). Flavanoids are observed to be higher in plant fruit peel and are advocated as food supplements. By scavenging oxygen radicals, flavanoids are recognized to be amazingly useful antioxidants. In addition, in biological environments, the protective properties of flavonoids are due to their ability to scavenge free radicals, chelates metal catalysis, stimulate antioxidant enzymes, reduce alpha-tocopherol radicals and suppress oxidases (Khan et al., 2017). It was reported that in refrigerated chicken and goat patties, the pomegranate components could be used as antioxidants (Karre et al., 2013). Higher antimicrobial and antioxidant activity of pomegranate peel extracts has recently been reported and may therefore be proposed as a safe natural alternative for synthetic antimicrobial agents (Rosas-Burgos et al., 2017). It was observed that 80% methanolic extracts of peels were a potent inhibitor of *Yersinia enterocolitica, Listeria monocytogenes, Staphyllococcus aureus* and *Escherichia coli*. Also, the existence of active inhibitors in peels, including phenolics and flavonoids, was also found by phytochemical research as potent constituents (Al-Zoreky, 2009). In addition, pomegranate is sufficient to inhibit the degradation of lipids and does not immensely affect the overall sensory properties of the final product (Abdel-Fattah et al., 2016).

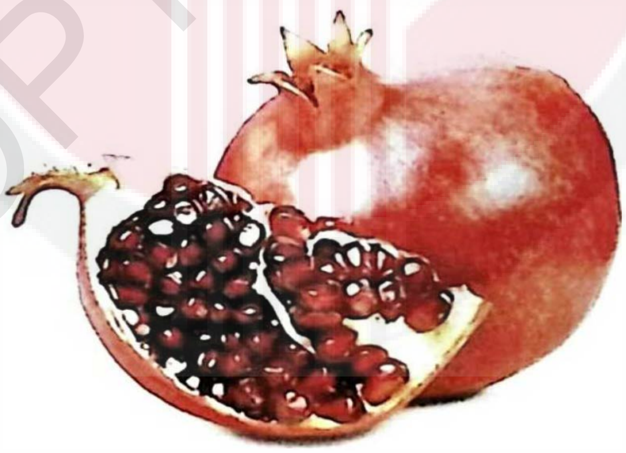

Figure 2.2 Pomegranate *(Punica granatum L.)*. Adopted from (Gabriele, 2014)

2.4 Banana (Musa Paradisicum) Peels

Another potential natural preservative that can be considered is banana *(Musa Paradisicum)* peel. Banana peel constitutes approximately 40% of the overall weight of fresh fruit (Anhwange et al., 2009). Banana peel contains bioactive chemicals such as phlobatannins, tannins, flavonoids, alkaloids, glycosides, terpenoids, and anthocyanins that can be used for their distinctive biological and pharmacological characteristics, such as antibacterial, antidiabetic, antihypertensive, and anti-inflammatory (Pereira & Maraschin, 2015). Recent research has shown that banana peel typically has higher phenolic compounds than banana pulp (Kondo et al., 2005; Someya et al., 2002). Furthermore, banana peel is rich in vitamins, dietary fibers, fats, calcium, and polyunsaturated fatty acids (Happi Emaga et al., 2007). Owing to its water retention property, neutral taste, and reducing cooking loss, the fiber in banana peel is advantageous for meat product production. Moreover, dietary fiber in its peel has various functional properties, such as the ability to form a gel, bind water, oil adsorption capacity, organic and mineral-binding capacity, which may boost the consistency and characteristics of meat products (Biswas et al., 2011). Several studies have shown that introducing fibers into the meat emulsion encourages water retention capacity, leading to low cooking loss (Zaini et al., 2020).

Figure 2.3 Banana *(Musa Paradisicum)*. Adopted from (Amazing Fact, 2017)

2.5 Effect of fruit peels addition on chemical compositions of meat-based products

The addition of fruit peel powder, decreasing the moisture content of the prepared beef patties as the concentration of pomegranate peel powder increases and even during different storage times. This was reported by Abdel-Fattah et al. (2016) where the moisture content of the control sample which prepared without pomegranate peels powder was 66.17% compared to 63.42%, 61.80%, and 59.13% for beef patties samples prepared with 1%, 2%, and 3% of pomegranate peels powder at the beginning of refrigerated storage period, respectively. These results agree with the one obtained by P. Sharma and Yadav (2020) that revealed that adding pomegranate peel powder to beef sausage contributed to a significant drop in moisture content.

P. Sharma and Yadav (2020) reported that the protein content of the control and the treated patties did not differ significantly when pomegranate peel powder has been added to chicken meat patties. This is in contrast with findings by Abdel-Fattah et al. (2016). It was reported that the protein content of beef patties samples prepared with 2% and 3%

pomegranate peel powder produced relatively higher protein content after 12 days of refrigerated storage. Also, Abdel-Fattah et al. (2016) stated that the protein content values of all samples decreased over time after being stored for 12 days of refrigerated storage at 4±1 °C. The reduction of the protein content of treated beef patties during storage might be attributed to the loss of soluble protein associated with the loss of beef patties water content and could be linked to the activity of proteolytic bacterial enzymes (Abdel-Fattah et al., 2016). The previous findings can be explained by the antimicrobial activity of the powder of pomegranate peels, while preserving and securing the effect against bacterial growth and the activity of their proteolytic enzymes, which in turn reflects the significant influence of the pomegranate peels on the protein content of the beef patties. Abdel-Fattah et al. (2016) published similar observations, where a decrease in the protein content of chicken patties incorporated with wheat and oat bran was observed.

The ash content in foods shows the total mineral content such as calcium, selenium, zinc, and phosphorus. These minerals are crucial for protein synthesis, muscular contraction, nerve propagation, and immune response function in human body (University of Michigan Health, 2020). The inclusion of pomegranate peels powder into prepared beef patties samples made the values of ash content to be slightly increased, in which it was also reported that higher percentage of peels powder promoted the higher ash content in the meat products. Similar results were reported by Sharma and Yadav (2020) where pomegranate peels powder treated chicken patties were significantly higher than control samples. A similar finding was reported by Zaini et al. (2020) where the ash content in the chicken sausage was found to increase as the added banana peel powder was increased.

Springmann et al. (2019) stated that reduced fat content in sausages resulted in lower product quality, particularly in terms of cook loss. According to McDonagh et al. (2005), regular fat beef patties had reduced water holding capacity and hence had more significant cook losses as well as the textural quality of the products was deteriorated. P. Sharma and Yadav (2020) reported that the introduction of pomegranate aril bagasse powder contributed to a significant increase in fat content. The results were significantly higher compared to fat content in control samples. Similar results were also reported by Abdel-Fattah et al. (2016), where the fat content of prepared beef patties samples was increased as the storage period increased and showed significant *($p<0.05$)* effect based on addition of pomegranate peels powder on refrigerated beef patties. Earlier studies like the inclusion of banana peel powder in chicken sausage also bear the same results (Zaini et al., 2020).

Fiber is beneficial for the preparation of meat products because it retains water, reduces cooking loss, and has a neutral flavor (Springmann et al., 2019). Dietary fibers derived from diverse plants have various functional properties, such as solubility, viscosity, gel formation ability, water binding capacity, oil adsorption capacity, and mineral and organic molecule binding capacity, all of which impact product characteristics and qualities (Tungland & Meyer, 2002). Water and dietary fibers derived from pea and wheat were utilized to replace beef patties, which enhanced water binding capacity, increased cooking output, reduced shrinkage, and lowered manufacturing costs without jeopardizing sensory characteristics (Besbes et al., 2008). Ajila et al. (2010) reported that there was a significant increase approximately 56% increment in total dietary fiber content contributed by 7.5% levels of mango peels in macaroni compared to control.

2.6 Effect of fruit peels addition on pH and TVBN values of meat-based products

A study by Warner (2014) stated that more than 95% of the water in a muscle at pH 7 is contained within cells; around 15% is in the extracellular space and emerges as a drip at the surface of the meat few days after death. Proteolysis of the cytoskeletal filaments occurs at this stage during aging, and more water is produced as drip with time. The same author also reported that dark, firm, and dry meat (DFD) and has a high final pH (>

6.2) tends to drip less. This is because the myofibrils have undergone slight transverse shrinking since the proteins in the myofibrils have a net negative charge at the high pH of DFD meat, causing the filaments to repel each other. When the pH of the muscle falls to 5.4 or below during rigor, the net charge on proteins in myofibrils drops, allowing filaments to connect and shorten the myofibril transversely. The pH values are 9.91 for banana peel powders (Stephen, 2016), 4.83 for pomegranate peel powders (Jalal et al., 2018), and 3-4 for orange peel powders (Pathak et al., 2017). Orange peels have the lowest pH values due to the abundance of vitamin C or known as ascorbic acid (Falade et al., 2003). On the other hand, banana peel is near to the alkaline scale due to malic acid, which makes up around 50-60% of a fully developed ripe banana, whereas citric acid makes up 20-25% and oxalic acid makes up 10-15% (Savitri, n.d.). The addition of these fruit peel powders into meat products would influence the overall pH values after mixing. It must be considered that beef meat has a pH of around 5.4-5.7 (Irkin et al., 2015).

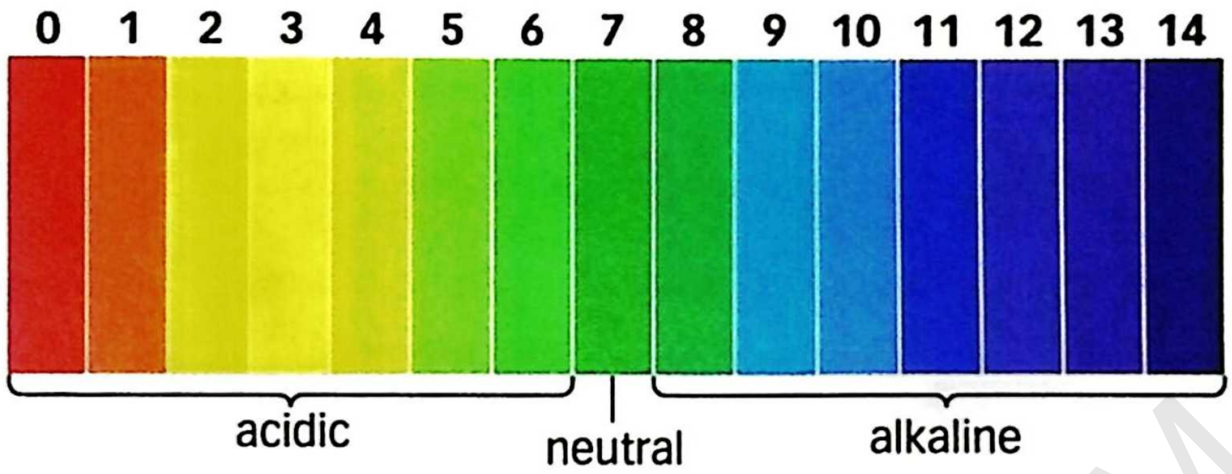

Figure 2.4 pH scales. Adopted from (Rufenacht, 2020)

The pH values for the beef patties incorporated with fruits peel powder showed a decrease in its value. A study by Abdel-Fattah et al. (2016) showed pH values of all samples are significantly *($p<0.05$)* decrease during refrigerated storage which the values are ranged from 6.61 to 6.65 at zero time and from 5.72 to 5.97 after 12 days after peels incorporation. It was also reported that there were no significant differences *($p<0.05$)* in the pH values of different beef patties samples prepared containing 0, 1, 2, and 3% of powdered pomegranate peels. Similar observations were found by (Mahmoud et al., 2017) where there was a reduction in pH in burger samples with orange peel additions *($p<0.05$)* at any level, and its pH varied from 6.22-6.54 compared to raw burger control samples which had pH 6.66.

The level of TVBN is extensively used as an indicator to assess the quality and shelf life of meat products, as it is a consequence of bacterial breakdown. The TVBN technique of analysis determines the degree of freshness by measuring the presence of nitrogenous chemicals such as ammonia, dimethyl and trimethylamine (VELP Scientifica, 2013). A study from Bekhit et al. (2021) showed TVB-N rises with meat storage and correlates with other deterioration indicators (i.e. function of duration, temperature, packaging, etc.) due to protein and amine degradation. According to the research made by Abdel-naeem and Malak (2020) on the effect of different fruits peel powder towards the TVBN reading of chicken patties sample, the results showed that the TVBN values for fruit peel powders handled with chicken patties did not vary significantly *($p>0.05$)* from those for control untreated chicken patties when the samples were analyzed at 0-time and during storage. Meanwhile, another findings made by Mahmoud et al. (2017), it was reported that TVBN values for beef patties, showing a significant difference *($p<0.05$)* between samples from different orange peel additive concentrations range from 2.5% until 10% inclusion. These additives (for any concentration) decreased the TVBN with a significant number *($p<0.05$)* relative to the control sample. This finding was supported with the one reported by Nassar and Sulaiman (2016) that found that lower TVBN after treatment of beef patties with orange peel powders. Reduction in TVBN happened because fruit peels contain high natural source of antioxidants, and they create antioxidative chemicals to endure and combat reactive oxygen species (Choubey et al., 2020). These fruit peels addition will help to extend the shelf life of food products by reducing lipid peroxidation and oxidative damage.

2.7 Effect of fruit peels addition on water holding capacity (WHC) and oil holding capacity (OHC) of meat-based products

One of the key quality characteristics of fresh meat is the water-holding ability (WHC). It affects significant characteristics such as possible drip loss, technological quality, appearance, and sensory attributes. WHC meat is also known to have an enormous influence on the tenderness, the thawing drip, and cooking loss of meat. The WHC can be impacted by prerigor myosin denaturation, sarcomere shortening, a decrease in muscle pH from 7 to 5.5, and the release of water from the muscle cell in response of cytoskeletal protein breakdown postrigor throughout tenderization (Warner, 2014). Oil-holding capacity (OHC) is a technical feature that depends on the surface qualities, overall charge density, thickness, and hydrophobic nature of the fiber particle and is related to the chemical composition of plant polysaccharides (Sendra-nadal et al., 2009).

The most common method of determining WHC and OHC is to use force to measure the amount of water expelled. The force can be applied externally as pressure by centrifugation, compression, or making use of capillary action, or it can be applied naturally through gravimetric methods (Warner, 2014). Based on the research conducted by M. Ibrahim et al. (2018), the lowest OHC and WHC values for control beef patties samples were observed relative to other formulated samples. The OHC increased in beef patties samples contained 2% orange peel, followed by 1% orange peel compared with the control. Viuda-Martos et al. (2012) explained that WHC is connected to soluble dietary fiber content, and high amounts of these fibers generate a high WHC value. This may be explained because soluble fibers, such as pectin and gums, have a greater WHC than cellulosic fiber. Thus, the higher WHC of lemon peel and orange peel may be attributed to chemical structures with a higher WHC content than the cellulosic fibers in the citrus peel (M. Ibrahim et al., 2018). In refrigerated beef patties, all the evaluated samples indicated a drop in WHC. Such results could be due not only to the decrease of particle size but also to the modification of the composition of the fiber matrix. The use of fibers into meat emulsion formulation increases the products' water retention ability (Springmann et al., 2019). Dietary fibers with smaller particle sizes have been associated to more inadequate water retention potential and oil binding ability (Sangnark & Noomhorm, 2003). Similar observations were reported by Zaini et al. (2020) where the WHC of chicken sausage sample increases with the addition of the banana peel powder.

2.8 Effect of fruit peels addition on cooking properties of meat-based products

Cooking loss is a mixture of liquid and soluble materials lost from the meat while cooking (Soyer et al., 2005). Cooking loss is a key element in meat production since it influences the cooking process's technical yield. From a nutritional standpoint, the cooking loss led in a loss of soluble proteins, vitamins, and other nutrients (Yarmand et al., 2013). The addition of pomegranate powder contributed to a decrease in the cooking loss of the sample of prepared beef patties, especially to levels 2 and 3%. The cooking loss, however, increased significantly *($p<0.05$)* as the refrigerated storage time continued. Based on the finding made by Abdel-Fattah et al. (2016) showed that for control samples and 1% pomegranate peels powder, the increase reached 27.34% and 19.73% after refrigerated storage at 4±1 °C for 12 days, respectively. However, the beef patties samples, which were prepared with 2 and 3% pomegranate peels powder, showed the lowest initial cooking loss, which is 18.52% and 16.84%, respectively.

Based on the finding proposed by M. Ibrahim et al. (2018), cooking yield percentage is improved in beef patties incorporated with orange or lemon peels powder was generally reported. The most significant low cooking yield was reported in the control sample. The control sample's cooking yield (%) decreased to 56.55% on the 6th day, from 66.05% at zero storage time. The cooking yields of the formulated sample of beef patties added with 1 or 2% orange peel improved compared to the control at zero time and were 71.17% and 71.66%, respectively. The cooking determinant findings revealed that the control sample showed significantly *($p<0.05$)* lower cooking yields than 1 or 2% orange and lemon peel powder samples. These results could prove that introducing the fruit peels powder into the meat product has improved its cooking characteristics. These results are in agreement with those obtained by Abdel-Fattah et al. (2016). It was reported that the incorporation of control and 1% pomegranate peel powder, respectively, showed the lowest initial cooking yield and reached values of 82.7% and 87.99%, respectively. These findings are accordance with Zaini et al. (2020) in which the cooking yield of chicken sausage sample increases with the addition of the banana peel powder. In the other hand, the beef patties samples prepared with 3% and 2% pomegranate peel powder showed 90.05% and 91.11%, respectively, the highest initial cooking yield. At the same time, all beef patties samples prepared showed a noticeable significant *($p<0.05$)* decrease in cooking yield during refrigerated storage at (4±1°C for 12 days). Such behaviour may be explained by the damage to dietary fiber granules found in burger and starch at various concentrations of pomegranate peel powder during cold and cooking processing, decreasing the ability of starch and dietary fibers in pomegranate peel powder to retain high quantities of water and swelling during cooking, thus allowing the heating media to lose moisture slightly (Aleson-carbonell & Ferna, 2005; Naveena et al., 2008).

Consumers frequently believe that shrinkage during cooking is an indicator of poor meat quality. Consumers are concerned about shrinkage because various thermal treatments induce undesired structural changes in meat, and increasing shrinkage is deemed inferior quality (Barbera & Tassone, 2006). It was reported that at zero time and on day 6 of storage, the shrinkage (%) of the control sample was 11.66 and increased to 15.79. This percentage was reduced at zero time for all formulated samples and its decrease was larger in the case of 2% orange peel or lemon peel samples. The rise in shrinkage percentage was also found by extending the storage time. The findings were in agreement with those mentioned by (Mahmoud et al., 2017). It was reported that the surface shrinkage of all cooked beef patties samples was significantly *($p<0.05$)* decreased in 10% orange peel comparing to control samples followed by 7.5% orange peel powder where it can be said that the improved shrinkage characteristics were due to the increased fat and water holding capacity.

2.9 Effect of fruit peels addition on color evaluation of meat-based products

Color is one of the most significant qualitative attributes that influence customer acceptance of meat products in the market. Instrumental (Lovibond tintometer/Hunter color Labs) or sensory assessment is used to assess the color (Springmann et al., 2019). Hunter Color Lab is the most advanced feature of a device that can accurately determine the color of meat products. Positive values for reddish colors and negative values for greenish colors are allowed for parameter a*. In contrast, positive values for yellowish colors and negative values for blue colors are allowed for parameter b*. L*is a rough approximation of luminosity (Pathare et al., 2013). The addition of fruit peel powders especially peel powders with high lightness, into the beef patties might help counter the dark color resulting from high pH dark cutting meat. The dark color is considered to be generated by internal light reflection, which prevents light from being reflected to a detector (human or machine) (Warner, 2014).

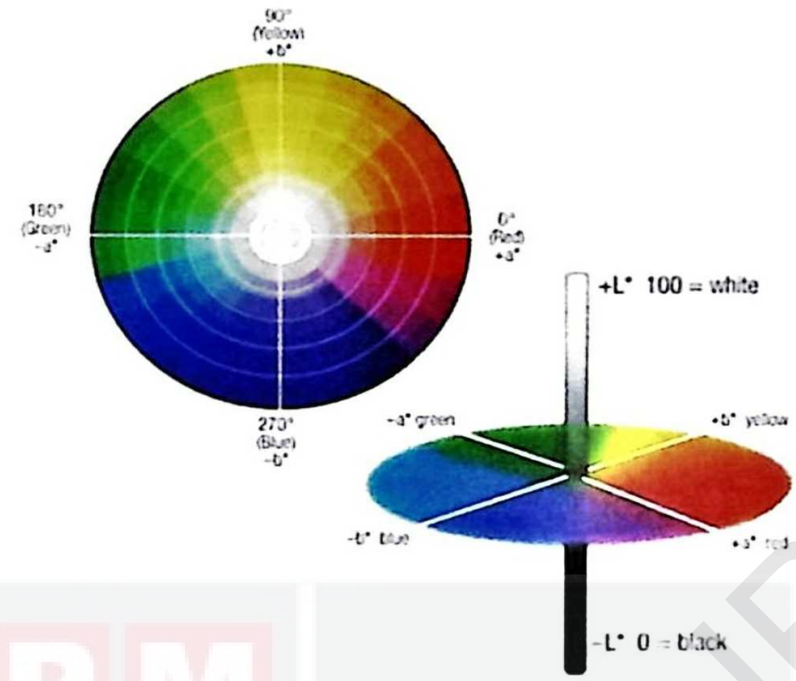

Figure 2.5 CIELAB Color Space. Adopted from (Cubillas & Japitana, 2016)

In color evaluation, the findings found by Abdel-naeem and Malak (2020) on the effects of different fruits peel powder towards the color of chicken patties, it was reported that the color values showed a significant *($p<0.05$)* decrease in lightness (L*) and redness (a*) in all fruit peel powders prepared with chicken patties relative to control untreated patties after processing (0-time) and during the storage period. The yellowness (b*) values were significantly *($p<0.05$)* higher in chicken patties treated with orange and lemon peel powders and were significantly *($p<0.05$)* lower in chicken patties processed with banana peel powders after processing (0-time) and over the entire storage period. A reduction in (b*) and (a*) beef patty values containing natural antioxidants has been reported by Moawad and Bareh (2014), who mentioned that the a* values of all patties samples decreased over storage time and became less red or brown due to the development of metmyoglobin. The reduction in the L* values of beef meatballs handled with lemon and orange extracts was explained by the rise in the retention of water that could be correlated with the hygroscopic properties of these products (Abdel-naeem & Malak, 2020).

2.10 Effect of fruit peel addition on texture profile analysis of meat-based products

Textural aspects are significant in the manufacture of processed meat products as they influence the satisfactoriness of consumers. The three primary components of food acceptance are texture, appearance, and flavor. Though there is no substitute for human sense for texture, the Instron Texture Analyzer is widely utilized. The spoilage of meat products leads to texture degradation and taste and color changes. It was reported by M. Ibrahim et al. (2018) for the research of the addition of orange peel powders towards the texture of cooked patties that compared to the other meat patties combined with (1% or 2%) orange or lemon peel powders, the hardness value of the control sample was significantly higher *($p>0.05$)*, except on the 15th day of storage.

Also, the hardness values increased significantly *($p<0.05$)* among all formulated samples as the percentage of orange or lemon peel powders increased, i.e., 2 % of orange peel and lemon peel is higher than the equivalent 1% hardness values. Compared to the control group, this hardness reduction of the formulated samples may be due to the inclusion of orange and lemon peels powder in patties, resulting in reduced protein binding (M. Ibrahim et al., 2018). Similar results were also obtained by Aleson-carbonell and Ferna (2005), whereas burgers with added albedo (in any form and concentration) were less rigid and gummier than the control. This reduction in hardness might explain the diluting impact of albedo in animal protein systems. Also, the test samples had slightly higher cohesiveness values than the control over the entire storage period. The cohesiveness values of the formulated samples were gradually increased for 1, 2% orange peel samples, then decreased for 1% lemon peel samples and increased again for 2%

lemon peel samples (M. Ibrahim et al., 2018). This was similar to the results of M. Ibrahim et al. (2018), which stated that the increase in the level of lemon albedo raised the cohesiveness of the substance *($p<0.05$)*, but the control was higher than the other samples. The addition of citrus peel powder to the product during the cooking stage might cause changes in its composition, increasing the springiness of the treatment products compared to the control. The result gained from M. Ibrahim et al. (2018) showed the springiness of 2% of the lemon peel sample was significantly *($p<0.05$)* higher than the control from zero to the 15th day of storage. However, there was a non-significant difference *($p>0.05$)* between the orange peel and lemon peel samples (1%, 2%). Similar results were obtained in beef patties incorporated with lemon albedo, which had a larger springiness value than control (Aleson-carbonell & Ferna, 2005). Throughout the storage time, the chewiness values of the control had slightly higher values than the values of formulated samples. Also, during the storage time (from zero to 15 days) it was observed that 1% of the orange peel or lemon peel samples had low chewiness values than 2% of the samples (M. Ibrahim et al., 2018). This finding was supported by Aleson-carbonell and Ferna (2005) in which decreases in the chewiness values of beef patties integrated with lemon albedo were also recorded. M. Ibrahim et al. (2018) claimed that the gumminess levels for the samples formulated were considerably higher than the control over the storage time under investigation. The gumminess of 1% and 2% orange peel and lemon peel samples were almost the same values on the 15th day of storage. With the increasing levels of powder citrus peel, gumminess values decreased, although the difference was not significant. A similar rising trend in beef patties gumminess values incorporated with lemon albedo has been observed (Aleson-carbonell & Ferna, 2005)

CHAPTER 3

METHODOLOGY

3.1 Material and methods

3.1.1 Preparation of dried fruit peels

Mature and acceptable orange, banana and pomegranate fruits were purchased from a local retail market (Econsave, Ipoh, Perak). The fruits were washed thoroughly, cut manually, and peels were manually removed, and their edible parts were carefully separated. The obtained peels were shredded into small pieces using a knife and were spread in trays and dried in a hot air oven at 60^0C for 48 hours. The dried fruit peels were cooled and grounded into a fine powder by using a kitchen grinder. The powder was sieved using a 30-mesh sieve before being packed in polyethylene bags and kept at 40°C until subsequent use.

3.1.2 Preparation of beef patties

Deboned beef meat with associated fats was obtained from local markets, Pasaraya BIG at Seri Serdang, Selangor was kept frozen at -18^0C. Different ingredients used in preparing beef pattiess e.g., starch, onion, salts, and spices mixtures including black pepper, nutmeg, cloves, coriander, etc. were obtained from local markets at Seri Serdang, Selangor. The cooled beef meat was ground using a kitchen grinder. Next, the ground beef meat was mixed with ingredients with their formulation as shown in Table 3.1. Three formulas were prepared from the batter mixture by addition of 1%, 2% and 3% as described by Abdel-Fattah et al. (2016) of total beef patties recipe of each fruits peel powder (orange, banana and pomegranate) and one formula was prepared as a control sample (without any fruits peel powder). Afterward, the mixture of each formula was manually formed into a disc-shaped of 90 grams, and 1-cm thickness using manual patties press former. Plastic packaging film was used to maintain the shape of the patties prior to freezing at -18^{0}C in a chest freezer until further use. The samples were thawed overnight before using at 4^{0}C. The proximate composition analysis pH determination, WHC, and OHC were performed immediately after defrosting, while the rest of tests were made on samples after cooking.

The samples were given a name as BPP1, BPP2, and BPP3 for 1, 2, and 3 % banana peel powders (BPP), and PPP1, PPP2, PPP3, for 1, 2, and 3 % pomegranate peel powders (PPP) and OPP1, OPP2, and OPP3 for 1, 2, and 3 % orange peel powders (OPP), respectively.

Table 3.1 Formulation in beef patties

Ingredients	Amount (g)	Ingredient: Spice's mixtures	Amount (g)
Ground beef meat	70	Black pepper	42.0
Sodium chloride	2.3	Red pepper	1.0
Water (as ice)	10	Cummins	25.0
Starch	4	Nutmeg	2.0
Garlic	0.5	All spice	19.0
Onion	2	Cloves	2.0
Spice's mixture	1.2	Cardamom	2.0
		Coriander	5.0

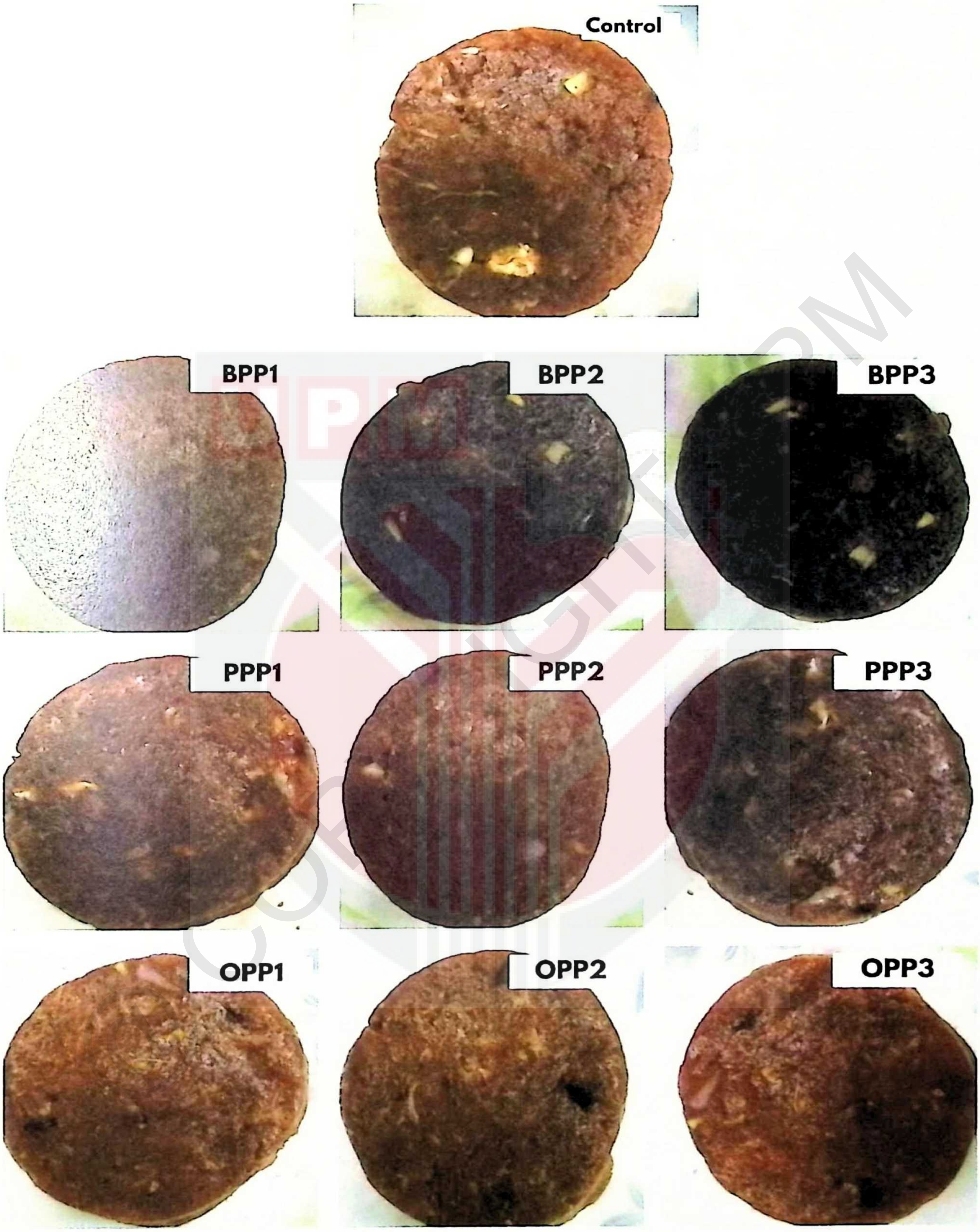

Figure 3.1 Prepared beef patties with 1,2,3% of banana, pomegranate, and orange peel powders

3.2 Chemical analysis of beef patties

3.2.1 Proximate composition analysis

The moisture, protein, fat, ash contents of raw beef patties were determined by using the method of AOAC (2000). In order to determine the moisture content (g% sample), 2 g of the sample was dried at 105^0C using drying oven (Memmert Oven, Germany) and leave for at least 7 hours until a constant weight was collected. Moisture content is calculated based on percentage of wet weight:

$$\% \, of \; wet \; weight = \frac{a-b}{a} \times 100 \qquad \text{Equation 3.1}$$

where, a=weight of sample used; b=dry weight of sample

The protein content (g% sample) was measured using In-house Method No: STP/Chem/A03 based on AOAC 20th Edition: 981.10, the Kjeldahl method of analysis. Protein content is calculated based on the percentage of nitrogen in a sample:

$$\% \, of \; nitrogen = \frac{(I_s - I_b) \times N \times 1.4}{W} \qquad \text{Equation 3.2}$$

$$\% \, protein = \% \, nirogen \times conversion \; factor \qquad \text{Equation 3.3}$$

where, W=weight of sample; I_s=volume of NaOH to titrate HCL; I_b=volume of NaOH to titrate blank; N=normality of NaOH

The fat (g% sample) was determined by Soxhlet Method by employing extraction method using petroleum ether (60°C to 80°C) as solvent and by the weight loss measurement. The raw sample was refluxed for 8 hours and was repeated until constant weight of fat extracted was obtained.

$$\% \, of \, oil \, in \, sample = \frac{M \times 100}{W} \qquad \text{Equation 3.4}$$

where, W=weight of sample (g); M=weight of oil (g)

Ash was measured by ignition of 3 g of raw sample at 550°C for 5 hours in the muffle furnace (SXL-1100M,Chemat Scientific, USA) until no black particles present in order to obtain permanent weight.

$$\% \, ash = \frac{(A - C) \times 100}{W} \qquad \text{Equation 3.5}$$

where, A=weight of crucible +ash; C=weight of crucible; W=weight of sample

Crude fiber content was determined In-house Method, Ref. No: STP/Chem/A08 based on AOAC 20th Edition, 962.09. 2 g defatted dried sample was measured and was subjected to acid (sulphuric acid) and alkali (sodium hydroxide) digestion. The residue left behind after digestion was weighed and ashed in the muffle furnace at 550°C until burn completely. The weight difference was estimated as crude fiber.

$$\% \, crude \, fiber = \frac{(S - K) - A \times 100}{W} \qquad \text{Equation 3.6}$$

where, W=weight of sample; K=weight of filter paper without ash; S=weight of crucible + filter paper + dried residue; A=weight of crucible + ash

3.3 Physicochemical quality criteria of prepared beef patties

3.3.1 pH value measurement

The pH values of the differently raw prepared beef patties samples were analyzed using the procedure as described by (Food Safety and Standard Authority of India, 2015). The prepared beef patties use a pH meter (PB-10 Basic Benchtop, Sartorius, Germany) by directly contacting the electrode's sensitive diaphragm and the meat tissue.

3.3.2 Total Volatile Basic Nitrogen (TVBN)

According to the method described using In-house Method No: STP/Chem/A03 based on AOAC 20th Edition: 981.10. The total volatile nitrogen content of differently raw prepared beef patties samples was carried out using the macrokjeldahl technique. 10 g of each beef patties sample was placed in a 500 mL kjeldahl flask with 300 mL distilled water and 2.0 g magnesium oxide, along with a drop or two of antifoam solution. The mixture was distilled, and the ammonia was obtained in a 4% boric acid solution, titrated with a hydrochloric acid solution (0.01N) in the presence of a composite indicator (bromocrysol green/methyl red). The results were calculated as g nitrogen (TVBN) per 100 g sample.

3.3.3 Water Holding Capacity (WHC) and Oil Holding Capacity (OHC)

The water-holding and oil-holding capacities were determined using the centrifugation technique with some modifications (Warner, 2014; Zaini et al., 2020). 2 g of each raw samples were weighed into centrifuge tubes. Next, 25 ml of distilled water (for WHC) or commercial cooking palm oil (Seri Murni, Malaysia) (for OHC) were added and stirred for uniform mixing. Next, by using Centrifuge (Universal320, Hettich, North America), the tubes were centrifuged at 9000 rpm for 10 minutes. The supernatant was drained for about 10 minutes and the residues were weight. The WHC and OHC calculated were in the form of weight of water and oil hold for 2 g sample, respectively. The WHC and OHC are calculated as follows:

$$WHC/OHC = \frac{weight\ after\ centrifuge\ (g) - weight\ before\ centrifuge (g)}{weight\ before\ centrifuge\ (g)} \times 100$$

Equation 3.7

3.4 Technology and qualities analysis

3.4.1 Cooking properties

Raw prepared beef patties samples were weighted before cooking. The beef patties samples were grilled by using the electric oven at 135°C and then allowed to cool to room temperature before next weighing. To estimate cooking yield, cooking loss, shrinkage, and moisture retention in the samples, the following calculation were used:

$$Cooking\ yield(\%) = \frac{Cooked\ weight\ (g)}{Raw\ weight\ (g)} \times 100$$

Equation 3.8

$$Cooking\ loss\ (\%) = \frac{Raw\ weight\ (g) - Cooked\ weight\ (g)}{Raw\ weight\ (g)} \times 100$$

Equation 3.9

$$Shrinkage(\%) = \frac{Raw\ diameter\ (cm) - Cooked\ diameter(cm)}{Raw\ diameter\ (cm)} \times 100$$

Equation 3.10

3.4.2 Color analysis

Color analysis of cooked beef patties were performed using the spectrophotometer (UltraScan PRO Spectrophotometer, Hunter Lab, USA) equipped with a D65 illuminant using CIE 1976 L*, a* and b* color scale. L* value is the brightness measurement (0-100); a* value is the red-green coordinate value (-green while + red); b* value is the blue-yellow coordinate value (-blue while + yellow). Color difference (ΔE*) was calculated from L, a and b parameters. For each sample, all measurements were done in triplicates at random locations on the surface.

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \qquad \text{Equation 3.11}$$

3.4.3 Texture profile analysis

Texture Profile Processing (TPA) was conducted with Texture Analyzer (TA.XTplus, Stable Micro System, United Kingdom) with optimal test conditions. After cooking, the samples were cooled to 4^0C. Cubic pieces (1×1×1 cm) were cut from patties and evaluated for two-cycle compression. The samples were crushed to 70% of their original height using a cylindrical probe 20 mm in diameter, a compression force of 5 kg, and a cross-head speed of 20 cm/min. The parameters obtained were hardness, springiness, gumminess, chewiness, and cohesiveness.

3.5 Sensory evaluation

30 panelists from the Food and Process Engineering Department, Faculty of Engineering subjected various prepared beef patties with different fruit peels for sensory evaluation. The sensory assessment was carried out by serving warm different ready beef patties samples after cooking. Each panelist tested all formulations in a randomized order and asked for the following qualities to be given a numerical score between 1 and 9: appearance, taste, odor, color, texture, and overall acceptability, where 9 denotes extremely reasonable, and 1 denotes extremely unacceptable.

3.6 Statistical analysis

All analyses were carried out in duplicate, and data were given as mean ± SD. The data were statistically submitted to one-way analysis of variance (ANOVA) using Minitab software. Differences were judged significant at the $p<0.05$ level.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Proximate analysis of beef patties with different percentages of peel powder

Table 4.1 Proximate composition of raw beef patties at different concentrations of banana, pomegranate, and orange peel powders

Proximate Component	Control	BPP1	BPP2	BPP3	PPP1	PPP2	PPP3	OPP1	OPP2	OPP3
Moisture (%)	77.20	73.75	74.10	70.15	71.30	70.45	72.60	65.85	67.20	75.75
Ash (%)	1.267	2.300	3.233	2.967	3.200	1.833	0.700	6.200	1.533	0.133
Protein (%)	17.28	15.64	15.77	14.02	15.71	14.45	14.15	15.59	14.73	14.29
Fat (%)	0.933	0.179	0.655	1.951	1.011	1.389	2.221	1.726	1.776	1.832
Fiber (%)	3.480	1.570	3.190	3.691	3.190	3.090	3.511	1.900	3.560	3.624

Data in Table 4.1 represents moisture, ash, protein, fat, and fiber content with banana, pomegranate, and orange peel additives at different concentrations of raw beef patties. Moisture content is one of the most important aspects of meat flavor, particularly tenderness and aroma. The obtained data showed a decrease in the moisture content of raw prepared beef patties with increasing concentration of all types of fruit peel powders used compared to control. Maximum moisture content was observed in treatment control which was 77.20%, while treatment of beef patties with OPP1 showed minimum moisture content which was 65.85%. Overall, samples with only up to 2% incorporation of banana peel powders could maintain high moisture almost near to the control with 4.5% differences between them. According to the observed results, the addition of different ratios of fruit peel powders resulted in a lower reduction in moisture content, and this is due to an improvement in water holding capacity, resulting in a lower loss rate in moisture content of beef patties samples treated with banana, pomegranate, and orange peel powders.

The maximum level of ash content was in beef patties with OPP1, while the minimum ash content showed at beef patties with OPP3. The ash contents of raw prepared beef patties were increased with the increasing addition of different ratios of all types of fruit peel powder. However, the ash contents of the beef patties incorporated with BPP3 started to decline from 3.233% (BPP2) to 2.967%. The reason of those increment and decrement might be related to peel powder's agglomeration where solid particles adhere to one another or to surfaces, reducing its solubility when too high concentration of peel powders were added. Meanwhile, beef patties with the addition of pomegranate and banana peel powders showed decreasing trend of ash content starting when 2% of powder concentration were added. It began to decline from 3.20% to 1.83% and to 0.70% for PPP and 6.20% to 1.53% and to 0.13% for OPP when the concentration of 1, 2, 3% of peel powders were used, respectively. This might be due to the greater mineral or ash content of fruit peel powders compared to beef meat.

Simultaneously, the protein content of various prepared beef patties samples followed the same pattern as the moisture content. The addition of all types of peel powders in beef patties resulted in a decrease in the protein contents. Abdel-Fattah et al. (2016) stated that the drop in protein content of treated beef patties with an increasing level of peels might be related to the loss of soluble protein associated with the loss of beef patties water content and could be connected to the activity of proteolytic bacterial enzymes. The fruit peels has antibacterial action while retaining and guaranteeing the impact against bacterial growth and the activity of their proteolytic enzymes, which shows the considerable influence on the overall beef patties protein content. Talukder and Sharma (2010) both came to similar conclusions as they discovered that chicken meat patties containing an increasing level of incorporation of wheat and oat bran had a lower protein level. They found that the protein contents started to decline from 21.1% to 20.4% for wheat bran chicken meat and from 21.1% to 20.7% for oat bran chicken meat at 5% and 15% levels of incorporation respectively. Next, beef patties incorporated with BPP1 showed among the highest protein content compared with control. At the same time, the sample with BPP1 also had the lowest fat content compared to other samples. This trend was supported by the findings by Abdel-naeem and Malak (2020). They reported an increase in protein content and a reduction in the fat contents of in chicken patties added with banana peel powders compared with those formulated with orange, grapefruits, and lemon peels powders. The obtained protein contents were 21.08, 18.79, 18.70, and 18.07%, and fat contents were 10.02, 12.95, 13.07, and 14.03%, respectively, for banana, orange, grapefruit, and lemon peels (Abdel-naeem & Malak, 2020).

The presence of fruit peel powders (for any concentration) did modify the fat content compared to control. The addition of banana, pomegranate, and orange peel powders contributed to a significant increase in fat content, and treatment of 3% pomegranate, banana, and orange peel powders had significantly highest fat content than control which were around 2.221, 1.951, and 1.832% compared to control which was only 0.933%. The 3% incorporation of all fruit peel powder levels treated patties had a greater fat content due to fat retention and the presence of more fat in its peels. Sharma and Yadav (2020) had reported in their study that pomegranate aril bagasse powders alone had a high fat content which was 16.86% that contributed to a greater fat content, 17.60% when chicken patties were incorporated with those powders' addition compared to control sample which had only 16.58%. The high value of fat contents was related to the high recorded value of oil holding capacity (OHC). Beef patties with 3% of banana and pomegranate peel powders which previously had the highest fiber contents, also had the highest OHC values among the treated samples, 0.770 and 0.710, as shown in Table 4.4, respectively.

Increasing the level of the addition of any types of fruit peel powders during the preparation of beef patties led to a significant increasing in fiber content as their values were 1.570, 3.190, and 3.691% for BPP, 3.190, 3.090, and 3.511% for PPP, 1.900, 3.560 and 3.624% for OPP, containing 1, 2 and 3% incorporation level of peels powder, respectively. Although dietary fiber has a notable tendency to retain water, the moisture content of the samples in this analysis decreased when the fruit peel powders addition was increased. The presence of a considerable of fiber might be the explanation for the increased WHC in Table 4.4. This is most likely due to the moisture content of fruit peel powders which is lower than the moisture level of beef patties. These findings were supported by Zaini et al. (2020), who reported that the banana peel powders used in their study comprised 11.11% moisture content which was so much lower than the moisture content of chicken meat which was 70.62%. They stated that the moisture content of chicken patties incorporated with banana peel powders were decreased from 70.12% (2% banana peel powders) to 66.94% (6% banana peel powders) even though banana peel powders have been proven to enhance water holding capacity with its higher fiber content which was around 1.70% compared to control which was only 0.83%. A similar observation was found by Talukder and Sharma (2010), who reported that because of the immense amount of soluble dietary fiber (leading to moisture entrapment and retention after heat application), oat bran emulsion had more emulsion stability than wheat bran emulsion in chicken meat patties.

Similar observations were made by Hughes et al. (1997), who outlined that adding oat fibers helped the hydration/binding characteristics, including emulsion stability and water-holding capacity of frankfurter to improve. Furthermore, the addition of dietary fiber, even in its dry state, induces a decrease in moisture in the treated samples (Yadav et al., 2018). As a result, adding fruit peel powders to beef patties during formulation enhanced their nutritional value. These findings will assist meat processors in low-income nations produce more excellent nutritional qualities and reduced costs.

4.2 Physicochemical analysis

4.2.1 pH analysis

Table 4.2 pH values of raw beef patties at different concentrations of banana, pomegranate, and orange peel powders

Sample	pH
Control	8.29 ± 0.067^{Aa}
BPP1	8.17 ± 0.007^{Aa}
BPP2	7.94 ± 0.064^{Ba}
BPP3	7.78 ± 0.014^{Bb}
PPP1	7.99 ± 0.086^{Aa}
PPP2	7.20 ± 0.014^{Ab}
PPP3	6.96 ± 0.021^{Ac}
OPP1	8.06 ± 0.141^{Aa}
OPP2	7.02 ± 0.325^{Bb}
OPP3	5.92 ± 0.042^{Cd}

*Mean with different capital letter (A, B) represents same types of fruit with different concentrations are significantly differ *($p<0.05$)*
** Mean with different small letter (a, b) represents same concentration with different types of fruit are significantly differ *($p<0.05$)*

One of the most essential quality tests for determining meat quality is pH. The importance of measuring pH is significant since it impacts several properties of meat and meat products, including color, water holding capacity, and texture (Andrés-Bello et al., 2013). The pH of meat is influenced by how much glycogen is in the muscle prior to slaughter. The conversion of glycogen in the meat to lactic acid after slaughter may be a critical determinant of changing the pH values of the meat (Hamma et al., 2020). Data in Table 4.2 showed there were significant differences *($p<0.05$)* among all treated samples of banana and orange at different peel concentrations. The incorporation of 2% and 3% fruit peel powders into the beef patties showed significantly *($p<0.05$)* decreased in pH values. Control recorded the highest pH 8.29. There was a reduction in pH value in raw beef patties samples of BPP, PPP, and OPP additions at any concentration, where pH is ranged from 5.92–8.17 compared to control samples in raw beef patties. The pH values of samples OPP3 is the lowest value recorded as it obviously decreased to be less than 6.00, which was a slightly acidic value. At the same time, beef patties with BPP1 registered the highest pH, which was 8.165, compared to control.

The pH values are 9.91 for banana peel powders (Stephen, 2016), 4.83 for pomegranate peel powders (Jalal et al., 2018), and 3-4 for orange peel powders (Pathak et al., 2017). Those values showed us the pH of fruit peels itself would influence and contribute to overall samples' pH after its incorporation. For instance, banana peel powders originally had higher pH compared to orange peel powders. Consequently, its addition with beef patties would give to a lower pH value but are not comparably low than samples with orange peel powders. The reason the treated beef patties showed different values that were so much lower compared to the solely corresponding fruit peel powder was due to the influence of the pH of beef meat. It must be taken into account that beef meat has a pH of around 5.4–5.7 (Irkin et al., 2015). Therefore, even though some peels, such as banana peel powders, have higher pH values, incorporating meat components with lower pH values would reduce the overall pH of the treated sample. The pH values of the beef patties treated with fruit peel powders were consistent with the findings of Fernández-López et al. (2004), who found a decrease in the pH of dry-cured sausages after adding lemon. According to Gorinstein et al. (2001), the greater content of organic acids (citric acid, malic, malonic, oxalic, and quinic acids) in citrus-treated chicken patties might explain the drop in pH values.

In addition to the unacceptable eating quality, high pH meat is also known as dark cutting meat because it has a purple appearance rather than the bright red color preferred by consumers, a coarse texture, a higher water holding capacity, a shorter shelf life (bacteria evolve more quickly due to the higher pH and moisture) and it appears undercooked while remaining pink in the center despite further cooking (Meat and Livestock Australia, 2011). Moreover, carcasses with a high pH (over pH 5.70) are rejected by Meat Standard Australia (MSA) grading. They are therefore unavailable to many meat brands, food service businesses, and marketplaces, including the profitable Japanese market, because consumers would reject dark-cutting meat because of its color at the retail level. Bacteria prefer environments close to pH 7.0, although they may sustain in a pH range of 4.6-7.0 (Richard, 1995). Thus, incorporating the fruit peel powders, especially the orange peel powders, into the meat products could be the good news to bring the pH values to low and acceptable values.

4.2.2 Total Volatile Basic Nitrogen (TVBN) analysis

Table 4.3 TVBN of raw beef patties at different concentrations of banana, pomegranate, and orange peel powders

Sample	TVBN (g/100g)
Control	2.77
BPP1	2.51
BPP2	2.50
BPP3	2.49
PPP1	2.50
PPP2	2.31
PPP3	2.26
OPP1	2.49
OPP2	2.36
OPP3	2.21

4.2.3 Water Holding Capacity (WHC) and Oil Holding Capacity (OHC)

Table 4.4 WHC and OHC of raw beef patties at different concentrations of banana, pomegranate, and orange peel powders

Sample	WHC	OHC
Control	0.846 ± 0.01^{Cd}	0.312 ± 0.07^{Cb}
BPP1	1.555 ± 0.02^{Ba}	0.583 ± 0.005^{Ba}
BPP2	1.703 ± 0.05^{Aa}	0.717 ± 0.002^{ABa}
BPP3	1.516 ± 0.03^{Ba}	0.770 ± 0.02^{Aa}
PPP1	1.076 ± 0.01^{Bb}	0.496 ± 0.03^{Bab}
PPP2	1.359 ± 0.001^{Ab}	0.451 ± 0.01^{BCab}
PPP3	1.040 ± 0.11^{BCd}	0.710 ± 0.04^{Aa}
OPP1	0.978 ± 0.04^{BCc}	0.478 ± 0.09^{Aab}
OPP2	1.302 ± 0.08^{Ab}	0.524 ± 0.12^{Aab}
OPP3	1.144 ± 0.01^{ABd}	0.578 ± 0.06^{Aa}

*Mean with different capital letter (A, B) represents same types of fruit with different concentrations are significantly differ *($p<0.05$)*
** Mean with different small letter (a, b) represents same concentration with different types of fruit are significantly differ *($p<0.05$)*

Meat's water-holding capacity may be likened to the activity of a sponge, and it is essential in meat processing because as proteins hold more water, they become more soluble (Knipe, 2003). The water holding capacity of meat products is a critical quality feature that influences product yield, which has economic consequences but is also significant in eating quality. In comparison to other formulated samples, control beef patties had the lowest OHC and WHC levels. The addition of all types of fruit peel at any concentrations into raw beef patties resulted in a significant *($p<0.05$)* increase in the WHC values. By comparing the varieties of fruit peel powders, raw beef patties incorporated with BPP exhibited the highest WHC and OHC values. Furthermore, in the WHC analysis, it has been revealed that the inclusion of 2% of any varieties of peel powders had the highest WHC values among all of the beef patties samples. Similar results were reported M. Ibrahim et al. (2018), where the addition of 2% orange peel in beef patties resulted in a rise of WHC up to 4.02 cm^2 whereas the control beef patties had a WHC of 1.50 cm^2. The findings that the addition of pomegranate peel powders could improve WHC level were also supported by Sharma and Yadav (2020) in comparison between pomegranate peel powder (PPP) and pomegranate aril bagasse powder (PABP) where WHC is increased up to 46.24% and 48.78% respectively compared to control which is 43.60%.

According to Viuda-Martos et al. (2012), WHC is proportional to the amount of soluble dietary fiber (SDF), and high amounts of SDF result in a high WHC level. This may be due to the greater WHC of soluble fibers such as pectin and gums compared to cellulose fibers. This was also in agreement with (Ali et al., 2011) where the dietary fiber content of banana peel powder might explain the rise in WHC. Water molecules occupy the pore area of fiber particles because dietary fiber is hydrated. Furthermore, the observed rise in WHC in the treated sample might be the result of high temperature-induced gelatinization of hydrated banana peel start. The reason that has contributed to the increased value of WHC in beef patties with pomegranate peel powder is due to the presence of dietary fiber (Cofrades et al., 2000). According to Viuda-Martos et al. (2012), it was found that the WHC of pomegranate bagasse powder co-product was 4.86 times its own weight.

Furthermore, the pH of meat has a significant impact on its ability to hold water. Increasing or decreasing the pH on either side of the isoelectric point (pI) will result in increased water holding capacity by establishing a charge imbalance. When positive or negative charges predominate, charged protein groups of the same (positive or negative) charge repel each other, causing a charge imbalance. This repulsion leads in enhanced water holding capacity, similar to the repulsive effect of like charges on two magnets (Knipe, 2003). Based on our findings, we found that samples with banana peel powders would offer higher WHC values due to connection with its relatively higher pH values (as in Table 4.2) compared to other treater samples, followed by pomegranate and orange peel powders. Huff-Lonergan and Lonergan (2005) reported that other than pH, the WHC of meat is influenced by postmortem processes such as proteolysis and even protein oxidation.

Next, the addition of BPP and PPP at any concentrations into beef patties resulted in a significant *($p<0.05$)* increased in the OHC values, while OPP caused in non-significant *($p>0.05$)* increased. The highest OHC content was when BPP3 (0.770) were used, while the lowest was in samples of PPP2 (0.450), compared to control. This could be explained by the relatively high fiber content in bananas. Huff-Lonergan and Lonergan

(2005) supported this, who proved that fruit and vegetable fiber had a higher oil binding capacity, which is important in emulsion-based products. Our findings also matched the hypotheses. The higher the fiber contents, the greater the OHC values, i.e., fiber contents were 3.691% (BPP3) and 1.570% (BPPl) would contribute to 0.770 0.583 OHC values, respectively. Not only that, Menezes et al. (2015) highlighted that fat needs special attention among its elements since its amount varies, which has a direct impact on emulsion stability as well as oxidative processes, emphasizing the necessity of understanding oil holding capacity. Based on our previous results as in Table 4.1, we found that some fruit peel powders such as BPP3, PPP3, and OPP3 that had among the highest fat contents, which were 1.951, 2.221, 1.832%, respectively, would also have higher OHC values which were 0.770, 0.710, and 0.578, respectively. A product's texture can be improved by adding a component having a high OHC. It may also be used to make meat products juicier after they have been cooked. Similar observations were reported by (M. Ibrahim et al., 2018). The inclusion of powdered citrus peel resulted in the lowest OHC readings for control beef patties samples compared to other prepared samples.

The total volatile basic nitrogen (TVBN) concentration is a chemical biomarker of meat quality that is linked to the amino acid decarboxylase growth of microorganisms during storage (Baltić et al., 2017). Based on Table 4.3, it is clear that these additions (for any concentration) for each type of fruit peel powders have decreased the total volatile basic nitrogen compared to the control sample, even though only minor changes were observed. The concentration of fruit peel powder additions influenced the TVBN values of raw beef patties as increasing the concentration of the peel would contribute to much lower TVBN. The lowest TVBN were obtained in beef patties with OPP3 (2.21 g/100g), while the highest values were in BPP1 (2.51 g/100g) compared to the control samples (2.77 g/100g). It was roughly observed that samples with banana peel powders had greater TVBN values when compared to most of the formulated samples. The total phenolic contents in banana peels are 0.90 to 3.0 g/100g (Fatemeh et al., 2012), 8.5 g/100g for pomegranate peels (Elfalleh, 2012), and 3.56 g/100g for orange peels (Sir Elkhatim et al., 2018). Those high contents of phenolic in each fruit peels were the greatest contribution to the reduction of TVBN values. This might be due to the high amount of phenolic and flavonoid chemicals in orange peel, which has antimicrobial action (Mahmoud et al., 2017). Microbes change their gene expression in response to this phenolic "attack" to lower aerobic metabolism and boost the synthesis of antioxidant and DNA repair enzymes. Suppression of aerobic metabolism limits microbial movement and biofilm formation, both of which are necessary for life (Kalogianni et al., 2020). On the other hand, Nassar and Sulaiman (2016) also reported decreased TVBN values after treating beef patties with orange peel powders.

4.3 Technology and quality analysis

4.3.1 Cooking properties

Table 4.5 Cooking properties of beef patties at different concentrations of banana, pomegranate, and orange peel powders

Sample	Cooking Yield (%)	Cooking Loss (%)	Shrinkage (%)
Control	69.76 ± 0.33^{Dd}	30.24 ± 0.33^{Aa}	19.41 ± 0.83^{Aa}
BPP1	77.76 ± 0.12^{Ba}	22.24 ± 0.12^{Cc}	15.88 ± 0.83^{Aa}
BPP2	80.16 ± 0.04^{Aa}	19.84 ± 0.04^{Dc}	2.353 ± 1.66^{Bb}
BPP3	75.92 ± 0.11^{Cb}	24.08 ± 0.11^{Bc}	2.941 ± 0.83^{Bc}
PPP1	75.38 ± 0.49^{Bb}	24.62 ± 0.49^{Cb}	13.53 ± 2.49^{Ba}
PPP2	77.94 ± 0.11^{Aa}	22.06 ± 0.11^{Dc}	1.77 ± 0.83^{Cb}
PPP3	73.27 ± 0.57^{Cc}	26.73 ± 0.57^{Bb}	11.76 ± 0.61^{Bb}
OPP1	74.38 ± 0.32^{Bb}	25.62 ± 0.32^{Bb}	13.55 ± 2.49^{Aa}
OPP2	73.04 ± 1.08^{Bb}	26.96 ± 1.08^{Bb}	1.765 ± 0.83^{Bb}
OPP3	77.75 ± 0.45^{Aa}	22.25 ± 0.45^{Cd}	17.06 ± 2.49^{Aab}

*Mean with different capital letter (A, B) represents same types of fruit with different concentrations are significantly differ *($p<0.05$)*

** Mean with different small letter (a, b) represents same concentration with different types of fruit are significantly differ *($p<0.05$)*

Table 4.5 shows the cooking properties of cooked beef patties at different concentrations for banana, pomegranate, and orange peel powders. It was observed that the cooking yield of all types of peel powder with an increasing level of peels added to beef patties was significantly higher *($p<0.05$)* than control samples. The increments represented additional improvements in cooking yield of beef patties with BPP2 had the highest recorded value, followed by samples with PPP2, BPP1 and OPP3. These yield values are obviously linked to fat and water retention. The highest yields shown in samples of BPP2 seem to be consistent with higher oil and water holding capacity. This finding is supported by Aleson-carbonell and Ferna (2005) and Hygreeva et al. (2014). The incorporation of fruit albedo fibers in beef patties formulation has increased cooking yield because of their ability to keep moisture and fat in the formulation. The orange peel's fat and water retention capacity appears to be connected to its soluble components, namely pectin, which can make up to 25% of the tissue and increase cooking quality (Lario et al., 2004).

According to Rocha-Garza and Zayas (1996), the ability of the protein matrix to retain water and bind fat determines quality attributes such as texture, structural binding, and yield in meat products. In this regard, carbohydrates and fiber have been successful in improving cooking yield, lowering formula costs, and improving texture. Moreover, increased cooking yield can be credited to improved emulsion stability and fruit peel powder's strong ability to retain moisture and fat in the matrix. According to some authors, fiber processing technique influences water and fat holding capacity, and therefore their chemical and physical structure, which is also connected to soluble dietary fiber content (Grigelmo-Miguel & Martín-Belloso, 1999).

Table 4.5 showed that the addition of BPP2 were particularly effective *($p<0.05$)*, reducing the cooking loss comparing to the control burger sample followed by PPP2, BPP1, and OPP3. However, the cooking loss was significantly *($p<0.05$)* increased when the percentage of banana peel powder and pomegranate peel powder increased from 19.84% (BPP2) to 24.08% (BPP3) and from 22.06% (PPP2) to 26.73% (PPP3), respectively. On the other side, the cooking loss for orange peel powders was decreased significantly *($p<0.05$)* from 26.96% (OPP2) to 22.25% (OPP3). It was undeniable that water and oil holding capacity play the important main role contributing to a change in cooking properties. By comparing the results in Table 4.5 and Table 4.4, we observed that samples with higher WHC and OHC would also have better cooking properties, such as higher cooking yield and lower cooking loss and shrinkage. For example, samples with BPP2 that had higher WHC and OHC values which were 1.703 and 0.717, had improved cooking properties obtained 80.16, 19.84, and 2.353% for cooking yield, cooking loss, and shrinkage in comparison with control which had so much poor and unacceptable properties for meat products. Abdel-Fattah et al. (2016), M. Ibrahim et al. (2018), and Sharma and Yadav (2020) also reported the same observation regarding the additions of fruit peel powders which were proven in enhancing the cooking properties of meat products.

Surface shrinkage is crucial for sustaining burger quality standards because it allows fat and water to escape from protein denaturation (Akesowan, 2015). The data in Table 4.5 showed that surface shrinkage of all cooked samples was significantly *($p<0.05$)* decreased compared to control samples. The addition of OPP2, PPP2, BPP2, and BPP3 had the lowest shrinkage percentage, which were 1.765%, 1.766%, 2.353%, and 2.941%, respectively. Concerning the shrinkage of different prepared beef patties samples, it could be noticed that beef patties which were control, OPP3, BPP1, and OPP1, showed the highest shrinkage and had reached the values of 19.41%, 17.06%, 15.88%, and 13.55%, respectively. Shrinkage happened because the unique meat proteins are denatured during cooking, resulting in structural alterations in the meat textural profile. Cell membranes were destroyed, meat fibers shrank, myofibrillar and sarcoplasmic proteins aggregation and gel formation occurred, and connective tissue shrank and solubilized (Tornberg, 2005). The results found were in agreement with (Abdel-Fattah et al., 2016), who found that adding 2% and 3% of pomegranate peel powder into beef patties could reduce the reduction in diameter up until 6.34% and 5.60%, respectively. The incorporation of fruit peel powders had a favorable influence on the cooking qualities of prepared beef patties samples, notably when the concentration of fruit peel powders was raised, especially up until the 2% addition of peel powder. The results agreed with Bessar (2008), who reported that increasing the concentration of orange and apple peels in foods will lead to a decrease in shrinkage.

4.3.2 Color analysis

Table 4.6 Color analysis of cooked beef patties at different concentrations of banana, pomegranate, and orange peel powders

Sample	Lightness (L*)	Redness (a*)	Yellowness (b*)	Color Difference (ΔE*)
Control	38.03 ± 0.13^{Aa}	2.53 ± 0.65^{Aa}	4.795 ± 0.30^{Aab}	61.82 ± 0.08^{ABabc}
BPP1	37.70 ± 0.28^{Aa}	1.539 ± 0.65^{Aa}	2.661 ± 0.60^{Ba}	61.98 ± 0.33^{Ba}
BPP2	29.75 ± 0.64^{Ba}	1.287 ± 0.53^{Aa}	0.152 ± 0.11^{Cd}	69.85 ± 0.63^{Aa}
BPP3	27.63 ± 0.71^{Ba}	0.575 ± 0.06^{A}	-1.001 ± 0.71^{Cc}	71.97 ± 2.11^{Aa}
PPP1	38.64 ± 0.71^{Aa}	4.211 ± 0.96^{Aa}	4.033 ± 2.23^{Aa}	61.28 ± 0.65^{Ba}
PPP2	35.78 ± 0.95^{ABa}	2.561 ± 0.64^{Aa}	3.075 ± 0.39^{Ac}	63.95 ± 0.46^{Ab}
PPP3	33.77 ± 0.75^{Ba}	1.462 ± 0.75^{Aa}	2.465 ± 0.64^{Ab}	65.90 ± 0.67^{Ab}
OPP1	38.73 ± 6.36^{Aa}	1.874 ± 0.35^{Aa}	4.585 ± 1.99^{Aa}	61.08 ± 0.65^{ABa}
OPP2	39.16 ± 6.35^{Aa}	2.12 ± 0.28^{Aaa}	6.873 ± 0.14^{Aa}	63.86 ± 0.79^{Ab}
OPP3	39.94 ± 7.40^{Aa}	2.730 ± 0.54^{Aa}	7.215 ± 0.95^{Aa}	60.55 ± 1.05^{Bc}

*Mean with different capital letter (A, B) represents same types of fruit with different concentrations are significantly differ *($p<0.05$)*
** Mean with different small letter (a, b) represents same concentration with different types of fruit are significantly differ *($p<0.05$)*

The color of meat products, without question, is the most essential indicator of freshness. Natural antioxidants have been shown to preserve the color stability of meat products by inhibiting lipid oxidation and preventing the conversion of meat metmyoglobin to oxymyoglobin (Andrés-Bello et al., 2013). Table 4.6 shows the hunter color parameters of cooked beef patties with different fruit peel additives at different concentrations. There was a significant *($p<0.05$)* decreasing trend of lightness (L*) for beef patties incorporated with increasing concentration of BPP and PPP, whereas there was a significant *($p<0.05$)* increasing trend of lightness value observed in the concentration of beef patties incorporated with increasing concentration of OPP when compared with control samples. The dark color contributed by banana and pomegranate peel powders may explain the significant fall in lightness in these treatments. According to Gonzalez and Rodriguez (1994), color is affected by various variables, but the drying process, in particular, impacts color. During the drying process, the peels were subjected to high temperatures, which causes enzymatic and non-enzymatic browning, resulting in product darkening. Lightness in food is affected by various factors, including the concentration and type of pigments present (Lindahl et al., 2001).

The redness parameter (a*) indicated a non-substantial difference between the treated samples and the control sample *($p>0.05$)*, with its value decreasing with a further addition of BPP and PPP in the beef patties. The addition of BPP3 and PPP3 caused the highest redness value reduction up to 77% and 43%, respectively, compared to the control group. On the other hand, the addition of OPP in beef patties led to non-significantly lower *($p>0.05$)* of redness (a*) in the concentration of 1% and 2% while non-significantly increase *(p>0.05)* in addition of 3% concentration when compared with control samples. The decreasing a* values might be related to interference with lipid oxidation in myoglobin oxidation (Selani et al., 2011). While comparing the samples containing different ratios of orange peel additives, it was found that the more orange peels ratio, the greater the red color in which increased from 1.84 to 2.12 then 2.73 in 1, 2, and 3%, respectively. These results agreed with Mahmoud et al. (2017), who found the redness of the beef patties were increased along with the increased concentration of orange peels additives from 11.14-11.45 then 11.83 in 5, 7.5, and 10%, respectively.

The yellowness attribute (b*) of beef patties incorporated with BPP was reduced significantly *(p<0.05)* while PPP was reduced non-significantly *(p>0.05)* when compared to the control samples with a significant difference among the tested samples. 2 and 3% peels incorporation showed significantly differences *(p<0.05)* in its b* values. The samples of BPP3 and PPP3 recorded the highest decrement in b* values which were up until 120% and 48%, respectively, when compared to control. In the case of yellowness of beef patties with the addition of OPP, the results showed that increasing orange peel levels resulting in increased *(p<0.05)* yellowness (b*) where the values ranged from 4.59, 6.87, and 7.22 at concentrations 1, 2, and 3%, respectively when compared with control samples. Also, the b* values of OPP treated beef patties were significantly higher than those of BPP and PPP treated beef patties. The yellowness of food increased with increasing amounts of orange peel powder as a source of carotenoid pigments due to citrus powder's yellow and orange color (Kammoun Bejar et al., 2011). This was in agreement with Aleson-carbonell and Ferna (2005), who found that a rise in b* value is due to the addition of yellowness and redness components found in lemon albedo to a sample of beef pattiess. It has been observed in this study that beef patties treated with banana and pomegranate peel powders exhibited lower L*, a* and b* values while beef patties treated with orange peel powders generally showing greater L*, a* and b* values.

Furthermore, we must note how pH has a significant impact on pigments (e.g., chlorophyll, carotenoids, anthocyanins, myoglobin, etc.) responsible for the color of fruits, vegetables, and meats (Andrés-Bello et al., 2013). Based on the previous discussion on the pH analysis, we found that BPP1 had the highest pH while OPP3 had the lowest pH. However, in this section, we observed that those big gap differences on pH value would lead to the only significant difference in L* values while non-significant which was no to little observation in a* and b* values. Schmidt and Trout (1984) discovered that even when cooked to the same internal temperature, high-pH beef, pig, and turkey muscle (pH[6.0]) was redder and seemed undercooked than low-pH muscle (pH[5.5]). According to these authors, the high-pH muscle decreased the quantity of myoglobin denatured at a given temperature. These were in line with our findings where we found that samples with BPP and PPP had increasing trend of redness (a*) values when the pH of the treated samples were also increased. For example, PPP1 (pH[7.99]) treated samples had a higher redness (a*) of 4.210, but PPP3 (pH[6.96]) treated samples had a lower redness (a*) of 1.460. Schmidt and Trout (1984) stated that the proportion of myoglobin denatured was significantly reduced in high-pH muscles, resulting in noticeable color differences in cooked meat. Similar observations were reported as in Table 4.6 where samples with BPP2 that had considerably higher pH (pH[7.94]) compared to others possessed notably higher color difference which was 69.85. Schmidt and Trout (1984) came to the conclusion that the pink hue in completely cooked high-pH beef products was due to two factors which were: (1) partial myoglobin denaturation at low temperatures (70 °C) and (2) development of a pink hemochrome at higher temperature (76 °C). Other than the influence of pH, the properties of cooked meat can be affected by the meat source, biochemical state of the muscle at time of slaughter and subsequent rigor mortis development, packing settings, freezing history, fat content, additional additives, and preservation methods such as irradiation and pressure (Andrés-Bello et al., 2013).

ΔE* (Total Color Difference) is a single value derived using delta L*, a*, and b* color differences and indicates the distance between the sample and the standard. The closer the sample is to the standard, the smaller the delta E* value. For example, beef patties of 2% and 3% BPP concentrations yielded the highest ΔE* (color difference) values of 71.97% and 69.85%, respectively, followed by beef patties treated with PPP3 which had ΔE* of 65.90%. In contrast, addition of OP3 had the lowest ΔE*, which was 60.55%, followed by sample incorporated with 1% pomegranate and banana peel powders, which were 61.28% and 61.98%, respectively. These results obtained were compared to the color scores provided by sensory evaluation panelists in Table 4.8.

4.3.3 Texture analysis

Table 4.7 Texture profile analysis of cooked beef patties at different concentrations of banana, pomegranate, and orange peel powders

Sample	Hardness g	Springiness %	Cohesiveness	Gumminess g	Chewiness % g
Control	210.86 ± 6.90^{Bc}	45.34 ± 5.33^{Aa}	0.954 ± 0.04^{Aa}	199.48 ± 15.96^{Bd}	9087.39 ± 1787.44^{Aba}
BPP1	333.96 ± 15.77^{Ab}	25.74 ± 6.72^{Aa}	0.926 ± 0.02^{Aa}	308.96 ± 6.86^{Ab}	7929.96 ± 1898.78^{Aa}
BPP2	347.02 ± 10.03^{Ab}	32.92 ± 5.28^{Aa}	0.879 ± 0.04^{Aa}	305.48 ± 24.76^{Ad}	10122.00 ± 2430.98^{Aa}
BPP3	388.65 ± 18.09^{Aa}	32.92 ± 6.68^{Aa}	0.841 ± 0.06^{Aa}	326.23 ± 9.65^{Ad}	10771.70 ± 2499.98^{Aa}
PPP1	430.78 ± 22.66^{Aa}	27.90 ± 8.12^{Aa}	0.912 ± 0.06^{Aa}	392.25 ± 5.24^{Aa}	10922.4 ± 3037.69^{Aa}
PPP2	420.00 ± 24.27^{Ab}	32.86 ± 9.37^{Aa}	0.877 ± 0.15^{Aa}	366.35 ± 44.10^{Ad}	11831.64 ± 1985.75^{Aa}

PPP3	404.00 ± 25.13^{Aa}	31.78 ± 6.21^{Aa}	0.849 ± 0.05^{Aa}	343.765 ± 44.39^{Ad}	10787.06 ± 723.59^{Aa}
OPP1	302.25 ± 6.548^{Cb}	25.77 ± 7.18^{Aa}	0.876 ± 0.03^{Aa}	264.57 ± 4.48^{Bc}	6801.96 ± 1785.27^{Ba}
OPP2	612.93 ± 28.86^{Aa}	28.46 ± 4.90^{Aa}	0.932 ± 0.10^{Aa}	572.53 ± 89.89^{Aa}	16073.69 ± 251.32^{Aa}
OPP3	167.87 ± 18.07^{Bc}	26.88 ± 4.24^{Aa}	0.975 ± 0.35^{Aa}	166.87 ± 77.40^{Bd}	4321.37 ± 1372.58^{Ba}

*Mean with different capital letter (A, B) represents same types of fruit with different concentrations are significantly differ *($p<0.05$)*
** Mean with different small letter (a, b) represents same concentration with different types of fruit are significantly differ *($p<0.05$)*

Consumers have certain expectations regarding the texture of meat products, such as beef patties in this case. Textural properties are crucial in the manufacture of processed meat products because they influence customer acceptance. Spoilage of meat products leads to texture deterioration as well as taste and color changes (M. Ibrahim et al., 2018). Meat texture characteristics are recognized by touch, either when the product is picked up by hand or when it is placed in the mouth and eaten. These qualities, in contrast to taste attributes, are very easy to assess using instrumental methods. A food's textural properties are a "group of physical characteristics that come up from the structural components of the food, are sensed through touch, are associated to the deformation, disintegration, and flow of the food under a force, and are measured objectively by functions of mass, time, and distance"(Barrett et al., 2010).

Texture profile analyses results of control and (1, 2, and 3%) of either banana, pomegranate, or orange peel powders formulated beef patties samples are depicted in Table 4.7. The hardness value of the control sample was significantly *($p<0.05$)* lower, except for samples with OPP3 as compared to the other samples mixed with (1, 2, or 3%) of banana, pomegranate, and orange peel powders. Among all the formulated samples, the hardness values increased significantly *($p<0.05$)* as the % of banana peel powders increased. In contrast, samples with pomegranate peel powders showed a decreasing trend starting from adding 2% of its peels. On the other hand, the inclusion OPP showed decreasing hardness values with the increasing level of powders incorporation starting from adding 3% of its peels from 612.93 g (OPP2) to 167.87 g (OPP3). Thus, PPP beef patties at any concentrations had significantly higher hardness than all treated samples except for OPP2 treated patties. In general, OPP3 samples had the smallest hardness values and substantially lower *($p<0.05$)* mean values than the other studied samples, including the control.

This reduction in hardness of the increasing level of peels samples compared to the control might be due to the inclusion of orange in patties, which resulted in lower protein binding. The diluting impact of albedo in animal protein systems may be responsible for the hardness reduction. Furthermore, the diluting impact of non-meat components in meat protein systems was largely responsible for the soft texture (M. Ibrahim et al., 2018). This is because the inclusion of nonmeat protein results in a stronger protein network that is more resistant to compression (Youssef & Barbut, 2011). Reduced moisture content in these treatments may have contributed to increased hardness. Kita et al. (2017) stated that the reduction in moisture content of hazelnuts after convective drying resulted in lower breaking point and hardness but higher springiness, cohesiveness, and chewiness. Several studies, on the other hand, have found that adding dietary fiber to meat products increased elasticity and decreased hardness.

According to our findings, we found that the addition of pomegranate and orange peel powders with high fiber contents could lead to lower hardness value compared to control, while banana peel powders showed a different trend where the hardness increased with an increasing percentage of its peel. Other than that, fat content also plays an important role in the hardness of the beef patties. The hardness of all cooked beef patties was considerably increased when the fat level (as in Table 4.1)was increased and these increment can be seen in samples at all level concentrations of BPP and only up until 2% incorporation level of PPP and OPP as they started to decline at 3% powders incorporation. Youssef and Barbut (2011) found a high correlation between fat content and hardness after replacing beef fat with canola oil or pre- emulsified canola oil (using soy protein isolate, sodium caseinate or whey protein isolate).

The strength of the molecular linkages inside a food product is called its cohesiveness (Sariçoban et al., 2009). Cohesiveness refers to how effectively a product withstands a second deformation in comparison to its resistance to the first. The all-tested samples had non-significantly *($p>0.05$)* lower cohesiveness values than control except for OPP3. The cohesiveness values of the treated samples were decreased gradually for 1, 2, and 3% BPP and PPP samples while increasing the level of OPP. This was in agreement with the findings of M. Ibrahim et al. (2018), who reported that the increase of orange and lemon levels in beef patties increased product cohesiveness *($p<0.05$)*, i.e., from 1.06 in control samples to 1.17 in 2% orange peel powders samples. High cohesion indicates that the adhesion is very strong, robust, and solid in and of itself, making it extremely resistant to tearing. Thus, samples with lower cohesiveness would be preferable for consumers to eat it because it is easier to tear them apart during chewing.

Moreover, as the fat percentage of the beef fat meat treatments increased, cohesiveness tended to decline. These trends were only applied in samples of BPP and PPP, while OPP showed the opposite trend as the fat contents increased. A similar trend resulting from the increased fat content could contribute to lower cohesiveness were reported by Youssef and Barbut (2011) on the study of texture profile of beef fat substituted with canola oil or pre-emulsified canola oil at various fat levels.

The springiness values of control samples were non-significantly *($p>0.05$)* higher than other formulated samples. The springiness of the beef patties continued non-significantly *(p>0.05)* to increase with an increasing percentage of banana peel powders and only up until 2% incorporation of both pomegranate and orange peel powders because the springiness started to reduce when 3% incorporation of these two fruits were used. The cooking process of products with added fruit peel powders may produce structural changes, resulting in an increase in the springiness of treated items as compared to control. A similar outcome was found in beef patties infused with lemon albedo, which had a greater springiness value than the control (Aleson-carbonell & Ferna, 2005). We must keep in mind that fat contents are very connected to springiness. Youssef and Barbut (2011) discover that springiness values rose when the amount of beef fat or pre-emulsified oil in the meat was increased, which may be explained by the fat/oil giving more elasticity (i.e., water does not contribute to springiness). These were in agreement with our findings where we observe non-significant *(p>0.05)* greater springiness in samples with fruits peel powders compared to control, even though only little observation was shown.

Gumminess values for the fruit peel powders formulated samples were significantly *(p<0.05)* higher compared to control. Different fruit peel samples with same concentration whether 1, 2, or 3% showed significant difference *(p<0.05)*. Gumminess values of OPP2 treated beef patties were significantly the highest, 572.53g, compared to control, due to their higher hardness values. An increasing trend in the gumminess values of beef patties added with 1 and 2% of OPP and later gradually had decreasing trend when OPP3 addition level was used. Meanwhile, increasing levels of pomegranate peel powders showed decreasing gumminess values from 392.25g to 366.35g and later to 343.765g at 1, 2, and 3% of peels incorporation levels. A similar observation was reported by Aleson-carbonell

& Ferna (2005), who observed the same increasing pattern in the gumminess values of the beef patties added with lemon albedo.

The chewiness values of the control had significantly lower values than the values of formulated samples except for BPP3, OPP3, and OPP3. Texture hardness impacts chewiness, with chewiness increasing as texture hardness rises. Chewiness values of all treated samples were significantly lower than OPP2 treated beef patties, which was due to their significantly lower hardness value and non-significantly lower springiness values. Also, it was noticed that PPP3 and OPP3 samples were of low chewiness values than 1 and 2% formulated samples of corresponding fruit peels. These were in contrast with BPP, where increasing BPP level did increase the chewiness value. M. Ibrahim et al. (2018) also reported a decrease in chewiness values of beef patties incorporated with orange and lemon peels compared to control, however, it had an increasing trend of chewiness as the concentration of peels were increased. When high-fat contents of fruit peels were used, chewiness and gumminess increased in the same way.

4.4 Sensory evaluation

Table 4.8 Sensory evaluation of cooked beef patties at different concentration of banana, pomegranate, and orange peel powders

Sample	Appearance	Color	Taste	Odor	Texture	Overall acceptability
Control	7.033 ± 0.99^{Aa}	6.833 ± 1.12^{Aa}	6.933 ± 1.66^{ABa}	7.133 ± 1.02^{Aa}	6.500 ± 1.19^{Aa}	7.300 ± 1.62^{Aa}
BPP1	7.033 ± 1.18^{Aa}	6.700 ± 0.87^{Aa}	6.800 ± 1.45^{Aa}	7.067 ± 0.74^{Aa}	6.667 ± 0.96^{Aa}	6.933 ± 1.08^{ABa}
BPP2	5.467 ± 1.11^{Bb}	5.200 ± 1.72^{Bb}	6.067 ± 1.45^{Aab}	6.200 ± 1.83^{ABb}	6.033 ± 1.45^{ABa}	6.200 ± 1.54^{BCb}
BPP3	4.333 ± 1.45^{Cc}	4.233 ± 1.94^{Cc}	4.733 ± 1.99^{Bb}	5.433 ± 1.77^{Bbc}	5.333 ± 1.69^{Bbc}	5.40 ± 1.61^{Cbc}
PPP1	7.133 ± 1.25^{Aa}	7.067 ± 1.55^{Aa}	7.033 ± 1.65^{Aa}	6.933 ± 1.29^{Aa}	6.600 ± 1.57^{Aa}	7.133 ± 1.46^{Aa}
PPP2	5.50 ± 1.46^{Bb}	5.40 ± 1.32^{Bb}	5.867 ± 1.55^{Cb}	6.033 ± 1.15^{Bb}	6.00 ± 1.37^{Aa}	6.067 ± 1.36^{Bb}

PPP3	5.333 ± 1.54^{Bb}	5.367 ± 1.37^{Bb}	5.933 ± 1.59^{BCa}	6.033 ± 1.19^{Bb}	6.067 ± 1.41^{Aab}	6.033 ± 1.37^{Bb}
OPP1	7.067 ± 1.46^{Aa}	7.200 ± 1.31^{Aa}	7.031 ± 1.464^{Aa}	7.467 ± 1.13^{Aa}	6.500 ± 1.13^{Aa}	7.100 ± 1.35^{Aa}
OPP2	6.033 ± 1.19^{Bb}	5.800 ± 1.38^{Bb}	5.567 ± 1.54^{Bb}	6.500 ± 1.33^{ABb}	6.067 ± 1.29^{Aa}	6.100 ± 1.24^{Bb}
OPP3	4.800 ± 1.54^{Cbc}	4.90 ± 1.58^{Bbc}	4.30 ± 1.15^{Cb}	5.367 ± 1.65^{Bc}	4.967 ± 1.45^{Bc}	5.00 ± 1.23^{Cc}

*Mean with different capital letter (A, B) represents same types of fruit with different concentrations are significantly differ *($p<0.05$)*

** Mean with different small letter (a, b) represents same concentration with different types of fruit are significantly differ *($p<0.05$)*

Table 4.8 shows that the sensory evaluation results for cooked beef patties samples prepared with different types of fruit peel at different concentrations. Data indicated that there were significantly *($p<0.05$)* lower scores for appearance, color, taste, odor, texture, and overall acceptability of beef patties samples with all fruit peel powder additives compared to control. There was decreased in sensory attributes parameters for any type of fruits by increasing fruit peel concentrations exceeding 2%. 2 and 3% peel concentrations showed significantly difference *($p<0.05$)* for all sensory aspects compared to control.

All beef patties containing fruit peel powders at 1% additive were well accepted and exhibited the maximum score of sensory properties compared to control. The 1% addition of fruit peels have proven to us that fruit peels could also contribute to the same excellent scores as the control samples without compromising its sensory characteristics. While, in the case of 3% additive of any fruit peels, the mean scores were lower, which indicated that samples were unacceptable compared to the 2% and 1%. The data also showed that the acceptability of beef patties containing PPP1 had higher total scores followed by OPP1 and BPP1. Furthermore, the scores for appearance, color, taste, and texture of PPP1 and OPP1 were non-significantly *($p>0.05$)* higher than control patties, while BPP1 was non-significantly *($p>0.05$)* higher than control sample only for texture. These results were in good agreement with M. Ibrahim et al. (2018). They obtained acceptable sensory scores for meat products treated with orange and lemon peels where the results showed that 2% orange peel powders and 2% lemon peel powder were more accepted with the higher score for overall acceptability, which was 7.94 and 8.31, respectively. The enhanced flavor of chicken patties treated with citrus fruit peel powders (orange, grapefruit, and lemon) was previously related to aromatic compounds generated as metabolites after treating organic acids (Kealey & Kinsella, 1979).

The greater levels of flavonoids components in these fruits may be responsible for the fruits' better taste evaluations (Ross & Kasum, 2002). However, if a high concentration of fruit peel powder were incorporated, there was a reduction in sensory scores because panelists' preference for the burger was generally associated with a low level of bitterness. The fact that the control beef patties sample had a less bitter flavor than the other burger samples was the major reason for its excellent score especially in its overall acceptability (as shown in Figure 4.1). The astringent flavor and bitterness found in burgers were produced by the alkaloids, tannins, and saponins found in orange fruit peel (Mahmoud et al., 2017).

By looking at the outset of the spider in Figure 4.1, OPP1 had the highest scores in odor and color aspects while BPP1 and PPP1 had excellent scores only for texture and appearance, respectively. These results indicate that the fruit peel powders could be added an amount of up to 3% in the formula of beef patties without adversely affecting the sensory characteristics of the burger. It is best to mention that 1% of any fruit peel powders supplemented in beef patties could be recommended to be produced as a burger with good quality acceptable sensory quality attributes while being a good source for bioactive compounds for food processing.

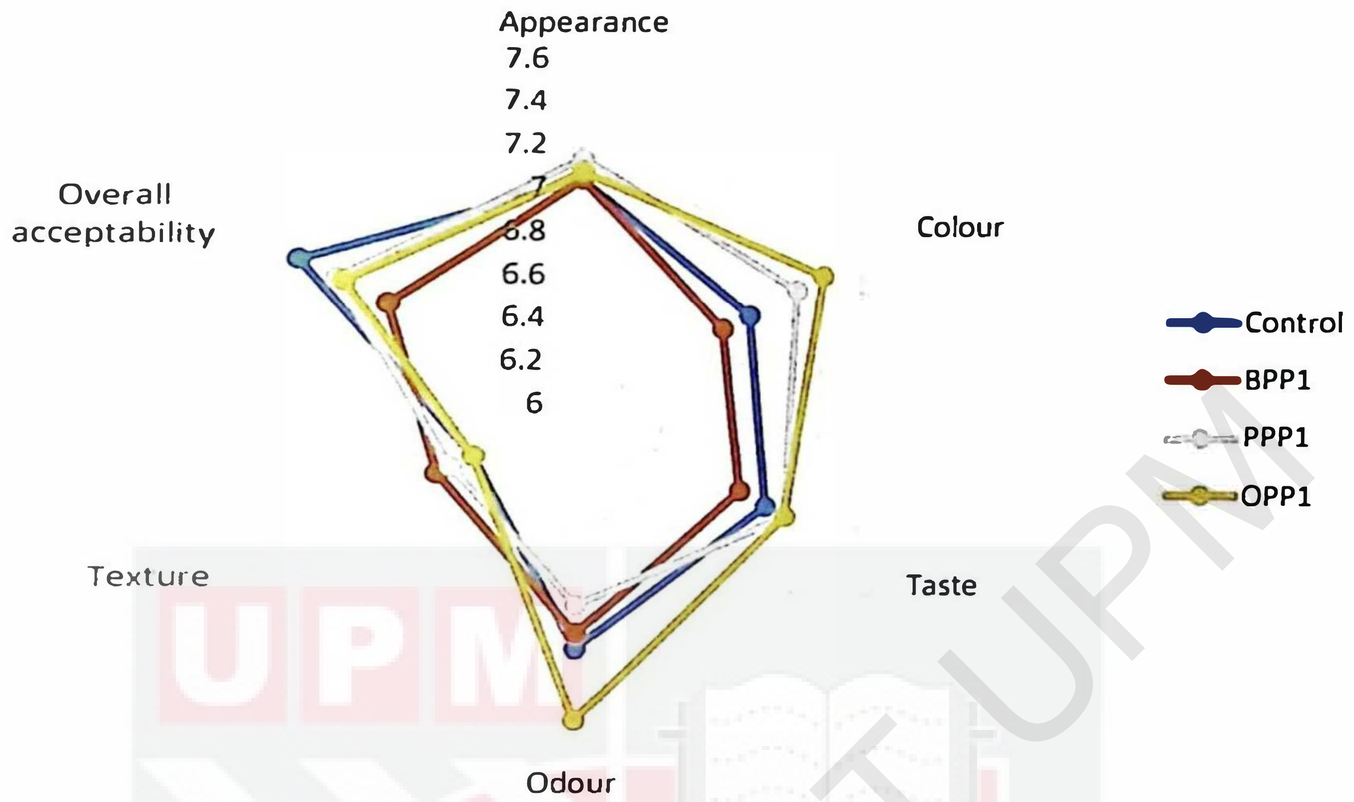

Figure 4.1 Radar chart of the best percentage of fruit peel powders.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The inclusion of fruit peel powders especially banana peel powders in beef patties, particularly at the 2% level, might be recommended to improve nutritional quality and enrich the burger with bioactive components, allowing it to become a functional meat product. In other words, though addition of high percentage of banana, pomegranate, and orange peel powders improved the nutritional properties, these additions at high concentration compromised color, texture, and taste of the beef patties. The use of 2% orange and pomegranate peel powders in the composition of beef patties had the maximum ability to enhance bacterial decomposition by reducing TVBN levels. OPP3 had the lowest pH and TVBN values which were 5.92 and 2.21, respectively. The technology and quality properties including WHC, OHC, cooking properties, color and texture of prepared beef patties samples were analyzed, and it was found that the addition of varied concentrations of fruit peels powder enhanced the quality criterion. The studies on cooking properties showed that the beef patties incorporated with banana peel powders up to 2% level resulted in products with excellent acceptability such as high cooking yield (80.16%) and low cooking loss (19.84%) and shrinkage (2.353%).

The improvement on the qualities of cooked beef patties were contributed by the higher WHC and OHC of the samples. Banana peel powders at 2 and 3% concentration levels had the outstanding values which were 1.703 and 1.516, respectively for WHC and 0.717 and 0.770, respectively for OHC. The color difference was the highest for BPP3 (71.97) and the lowest for sample of OPP3. The hardness of cooked beef patties was increased with increasing level of peel powders additions that would also lead to higher gumminess and chewiness. However, the chewiness and cohesiveness of treated beef patties with fruit peel powders were reduced compared to control. At the same time, utilization of the percentage of fruit peel powders could be useful to achieve high stability of beef patties with positive effects on the sensory characteristics of the product by having high scores that is near to control especially for the addition of 1% for all types of fruit peel powders. In this context, PPP1 had the highest overall acceptability which were 7.133, only 2.33% score differences with control samples.

The development and usage of such functional and nutritional food materials may be utilized to enhance the nutritional status of the population, which can have a positive impact on health by avoiding degenerative diseases. Furthermore, by enhancing the nutritional content of the product and decreasing the formulation cost, they might benefit the industry and customers. As a result, in beef meat processing sector, these peel powders might be used as a natural source of antioxidants, antimicrobial, texture enhancer, and health-promoting functional elements.

5.2 Recommendations

The findings of this study's analysis have been provided, along with a discussion of the quality characteristics of beef patties as influenced by different varieties of peel powder. With this explanation, all relevant researchers may take action and make an effort to regulate the types and percentage of fruit peel powders in food incorporation to keep it at an ideal level. Finally, it is suggested that further research be done to completely comprehend the ideas of adding fruit peels in food-based products need to be continued.

Some recommendation that can be considered are to study the effect of particle size of the powders as the particle size increases, the flow of the powders increases as well, until it reaches a point where it is free flowing. The flow characteristics are improved by a suitable mix of coarse and fine particles, or by choosing the right particle size distribution. Particle size distribution is critical for understanding a material's physical and chemical characteristics, making it an excellent hygiene and quality assurance tool for producers in a wide range of sectors.

Other than that, extensive studies to find the optimum cooking conditions for different types of fruit peel powders such as implementing the kinetic modelling , heat and mass transfer and transport phenomena should be performed because in order to improve cooking process. This is critical for the discovery of novel food products, the more cost-effective and energy-efficient processing of current food sources, improved food quality and quality control, and compliance with new requirements such as nutritional labeling and shelf-life dates.

REFERENCES

Abdel-Fattah, A. ., Abdel-Rahman, N. R., Abd El-Razik, M. M., & El-Nashi, B. (2016). *Utilization of Pomegranate Peels for Improving Quality Attributes of Refrigerated Beef Burger*. 427–441.

Abdel-naeem, H., & Malak, M. (2020). *Improving the physico-chemical , sensory and bacterial quality of chicken patties using fruit peels powders. July 2019.*

Ahmad, S. R., Gokulakrishnan, P., Giriprasad, R., & Yatoo, M. A. (2015). Fruit-based Natural Antioxidants in Meat and Meat Products: A Review. *Critical Reviews in Food Science and Nutrition*, *55*(11), 1503–1513. https://doi.org/10.1080/10408398.2012.701674

Ajila, C. M., Aalami, M., Leelavathi, K., & Rao, U. J. S. P. (2010). Mango peel powder: A potential source of antioxidant and dietary fiber in macaroni preparations. *Innovative Food Science and Emerging Technologies*, *11*(1), 219–224. https://doi.org/10.1016/j.ifset.2009.10.004

Akesowan, A. (2015). Optimization of light pork burgers Linseed/sunflower, formulated with canola oil and seed/almond (LSA) mix. *J. Anim. Plant Sci.*, *25*, 268–277.

Al-Zoreky, N. S. (2009). Antimicrobial activity of pomegranate (Punica granatum L.) fruit peels. *International Journal of Food Microbiology*, *134*(3), 244–248. https://doi.org/10.1016/j.ijfoodmicro.2009.07.002

Aleson-carbonell, L., & Ferna, J. (2005). *Characteristics of beef burger as influenced by* *various types of lemon albedo. 6,* 247–255. https://doi.org/10.1016/j.ifset.2005.01.002

Ali, R. F. M., El-Anany, A. M., & Gaafar, A. M. (2011). Effect of potato flakes as fat replacer on the quality attributes of low-fat beef patties. *Advance Journal of Food Science and Technology*, *3*(3), 173–180.

Amazing Fact. (2017). *Diet friendly to keeping cancer away, know surprising facts about bananas.* https://www.naukrinama.com/stressbuster/amazing-facts-about-banana/

Andrés-Bello, A., Barreto-Palacios, V., García-Segovia, P., Mir-Bel, J., & Martínez-Monzó, J. (2013). Effect of pH on Color and Texture of Food Products. *Food Engineering Reviews*, *5*(3), 158–170. https://doi.org/10.1007/s12393-013-9067-2

Anhwange, B. A., Ugye, T. J., & Nyiaatagher, T. D. (2009). Chemical composition of Musa sapientum (Banana) peels. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, *8*(6), 437–442.

Augusto, A., Santiago, C., & Gindri, G. (2009). *The effect of glaze uptake on storage quality of frozen shrimp. 90,* 285–290. https://doi.org/10.1016/j.jfoodeng.2008.06.038

Ayala-Zavala, J., & González-Aguilar, G. (2010). *Use of Additives to Preserve the Quality of Fresh-Cut Fruits and Vegetables.* 231–254. https://doi.org/10.1201/b10263-10

Baltić, T., Ćirić, J., Velebit, B., Petronijević, R., Lakićević, B., Dordević, V., & Janković, V. (2017). Changes in total viable count and TVB-N content in marinated chicken breast fillets during storage. *IOP Conference Series: Earth and Environmental*

Science, *85*(1). https://doi.org/10.1088/1755-1315/85/1/012073

Barbera, S., & Tassone, S. (2006). Meat cooking shrinkage: Measurement of a new meat quality parameter. *Meat Science*, *73*(3), 467–474. https://doi.org/10.1016/j.meatsci.2006.01.011

Barrett, D. M., Beaulieu, J. C., & Shewfelt, R. (2010). Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: Desirable levels, instrumental and sensory measurement, and the effects of processing. *Critical Reviews in Food Science and Nutrition*, *50*(5), 369–389. https://doi.org/10.1080/10408391003626322

Bekhit, A. E.-D. A., Holman, B., Giteru, S., & Hopkins, D. (2021). Total volatile basic nitrogen (TVB-N) and its role in meat spoilage: A review. *Food Science and Technology*, *109*, 280–302. https://doi.org/https://doi.org/10.1016/j.tifs.2021.01.006

Besbes, S., Attia, H., Deroanne, C., Makni, S., & Blecker, C. (2008). Partial Replacement Of Meat By Pea Fiber And Wheat Fiber: Effect On The Chemical Composition, Cooking Characteristics And Sensory Properties Of Beef Burgers The use of dietary fiber and water for meat replacement in beef burger formulation was investigate. *Journal of Food Quality*, *31*(2008), 480–489.

Bessar, B. A. (2008). Effect of using orange and apple peel as fat replacers on the sensory, physical and nutritional evaluation of beef burgers. *J. Agric. Kafr El-Sheikh Univ*, *34*, 1035–1056.

Biswas, A. K., Kumar, V., Bhosle, S., Sahoo, J., & Chatli, M. K. (2011). Dietary fibers as functional ingredients in meat products and their role in human health. *International*

Journal of Livestock Production, *2*(4), 45–54. http://www.academicjournals.org/IJLP

Can-cauich, C. A., Sauri-duch, E., Betancur-ancona, D., Chel-guerrero, L., González-aguilar, G. A., Cuevas-glory, L. F., Pérez-pacheco, E., & Moo-huchin, V. M. (2017). *Tropical fruit peel powders as functional ingredients : Evaluation of their bioactive compounds and antioxidant activity*. *37*, 501–506. https://doi.org/10.1016/j.jff.2017.08.028

Choubey, S., Katekar, G., Pawar, P., & Godbole, S. (2020). Extraction and Evaluation of Anti-Oxidants from Fruit Peels and Its Utilization in Paneer to Increase its Shelf-Life. *International Journal of Advanced Scientific Research and Management*, *5*(1), 12–21. https://doi.org/10.36282/ijasrm/5.1.2020.1679

Cofrades, S., Guerra, M. A., Carballo, J., Fernández-Martín, F., & Jiménez Colmenero, F. (2000). Plasma protein and soy fiber content effect on bologna sausage properties as influenced by fat level. *Journal of Food Science*, *65*(2), 281–287. https://doi.org/10.1111/j.1365-2621.2000.tb15994.x

Cubillas, J. E., & Japitana, M. V. (2016). Ortho image classification of benthic habitats in hinatuan, surigao del sur, philippines using cielab, color constancy and intesity as features. *Phil-LiDAR 2.B.14 Caraga State University in International Symposium on Remote Sensing (ISRS)*, *April*. https://www.researchgate.net/publication/332013468_ORTHO_IMAGE_CLASSIFICATION_OF_BENTHIC_HABITATS_IN_HINATUAN_SURIGAO_DEL_SUR_PHILIPPINES_USING_CIELAB_COLOR_CONSTANCY_AND_INTESITY_A

S_FEATURES

Decker, E. A., Chan, W. K. M., Livisay, S. A., Butterfield, D. A., & Faustman, C. (1995). Interactions Between Carnosine and the Different Redox States of Myoglobin. *Journal of Food Science*, *60*(6), 1201–1204. https://doi.org/10.1111/j.1365-2621.1995.tb04555.x

Devatkal, S. K., Thorat, P., & Manjunatha, M. (2012). *Effect of vacuum packaging and pomegranate peel extract on quality aspects of ground goat meat and nuggets*. https://doi.org/10.1007/s13197-012-0753-5

El-khalek, H. H. A., & Zahran, D. a. (2013). *Utilization of Fruit by-Product in Ground Meat Preservation*. *6088*, 49–61.

El-nashi, H. B., Fattah, A., Karim, A., Fattah, A., Rahman, N. R. A., & El-razik, M. M. A. (2015). *Quality characteristics of beef sausage containing pomegranate peels during refrigerated storage*. *60*, 403–405.

Elfalleh, W. (2012). Total phenolic contents and antioxidant activities of pomegranate peel, seed, leaf and flower. *Journal of Medicinal Plants Research*, *6*(32), 4724–4730. https://doi.org/10.5897/jmpr11.995

Falade, O. S., Sowunmi, O. R., Oladipo, A., Tubosun, A., & Adewusi, S. R. A. (2003). The Level of Organic Acids in Some Nigerian Fruits and their Effect on Mineral Availability in Composite Diets. *Pakistan Journal of Nutrition*, *2*(2), 82–88. https://doi.org/10.3923/pjn.2003.82.88

Fatemeh, S. R., Saifullah, R., Abbas, F. M. A., & Azhar, M. E. (2012). Total phenolics, flavonoids and antioxidant activity of banana pulp and peel flours: Influence of variety and stage of ripeness. *International Food Research Journal*, *19*(3), 1041–1046.

Fernández-López, J., Fernández-Ginés, J. M., Aleson-Carbonell, L., Sendra, E., Sayas-Barberá, E., & Pérez-Alvarez, J. A. (2004). Application of functional citrus by-products to meat products. *Trends in Food Science and Technology*, *15*(3–4), 176–185. https://doi.org/10.1016/j.tifs.2003.08.007

Fernández, J., Pérez-Álvarez, J. A., & Fernández-López, J. A. (1997). Thiobarbituric acid test for monitoring lipid oxidation in meat. *Food Chemistry*, *59*(3), 345–353. https://doi.org/10.1016/S0308-8146(96)00114-8

Food Safety and Standard Authority of India, G. of I. (2015). Manual of Methods of Analysis of Foods Food Additives. *Food Safety and Standards Authority of India*.

Gabriele, E. (2014). *VIII Edizione del Meeting " Nuove Prospettive in Chimica Farmaceutica " Book degli Abstracts. January*.

Gonzalez, R., & Rodriguez, A. (1994). Sugar cane forage for milk production. Effect of the inclusion of star grass (Cynodon nlemfuensis) forage on rumen liquor turnover. *Cuban J Agric Sci*, *28*, 285–287. https://agris.fao.org/agris-search/search.do?recordID=CU9600380

Gorinstein, S., Martín-Belloso, O., Park, Y. S., Haruenkit, R., Lojek, A., Íž, M., Caspi, A., Libman, I., & Trakhtenberg, S. (2001). Comparison of some biochemical characteristics of different citrus fruits. *Food Chemistry*, *74*(3), 309–315.

https://doi.org/10.1016/S0308-8146(01)00157-1

Grigelmo-Miguel, N., & Martín-Belloso, O. (1999). Comparison of Dietary Fibre from By-products of Processing Fruits and Greens and from Cereals. *LWT - Food Science and Technology*, *32*(8), 503–508. https://doi.org/10.1006/fstl.1999.0587

Hamma, A. A., Dahir, H. G., Khidhir, Z. K., Mohammad, M. M., Ahmmed, D. J., & Ahmmed, A. K. (2020). Effect of Lemon Peel and Pulp Extract on Some Local Kurdish Ram Meat Qualities and Its Shelf Life. *Anbar Journal of Agricultural Sciences*, 140–153. https://doi.org/10.32649/ajas/2020/13

Happi Emaga, T., Andrianaivo, R. H., Wathelet, B., Tchango, J. T., & Paquot, M. (2007). Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. *Food Chemistry*, *103*(2), 590–600. https://doi.org/10.1016/j.foodchem.2006.09.006

Haque, F., Rahman, M. H., Habib, M., Alam, M. S., Monir, M. M., & Hossain, M. M. (2020). *Effect of Different Levels of Orange Peel Extract on the Quality and Shelf Life of Beef Muscle during Frozen Storage*. *13*(1), 43–56. https://doi.org/10.9790/2380-1301044356

Hawthorn, J. (1969). Organisms in Foods. In *Nature* (Vol. 224, Issue 5215). https://doi.org/10.1038/224196b0

Huff-Lonergan, E., & Lonergan, S. M. (2005). Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. *Meat Science*, *71*(1), 194–204. https://doi.org/10.1016/j.meatsci.2005.04.022

Hughes, E., Cofrades, S., & Troy, D. J. (1997). Effects of fat level, oat fibre and carrageenan on frankfurters formulated with 5, 12 and 30% fat. *Meat Science*, *45*(3), 273–281. https://doi.org/10.1016/S0309-1740(96)00109-X

Hygreeva, D., Pandey, M. C., & Radhakrishna, K. (2014). Potential applications of plant based derivatives as fat replacers, antioxidants and antimicrobials in fresh and processed meat products. In *Meat Science* (Vol. 98, Issue 1). Elsevier B.V. https://doi.org/10.1016/j.meatsci.2014.04.006

Imaida, K., Fukushima, S., & Shirai, T. (1983). *Promoting activities of butylated hydroxyanisole and butylated hydroxytoluene on 2-stage urinary bladder careinogenesis and inhibition of y-glutamyl transpeptidase-positive foci development in the liver of rats*. *4*(7), 895–899.

Irkin, R., Dogan, S., Degirmenioglu, N., Diken, M. E., & Guldas, M. (2015). Phenolic content, antioxidant activities and stimulatory roles of citrus fruits on some lactic acid bacteria. *Archives of Biological Sciences*, *67*(4), 1313–1321. https://doi.org/10.2298/ABS140909108I

Jalal, H., Pal, M. A., Ahmad, S. R., Rather, & Andrabi, Mudasir and Hamdani, S. (2018). Physico-chemical and functional properties of pomegranate peel and seed powder. *The Pharma Innovation Journal*, *7*(4), 1127–1131. www.thepharmajournal.com

Jayathilakan, K., Sultana, K., Radhakrishna, K., & Bawa, A. S. (2012). Utilization of byproducts and waste materials from meat, poultry and fish processing industries: A review. *Journal of Food Science and Technology*, *49*(3), 278–293.

https://doi.org/10.1007/s13197-011-0290-7

Kalogianni, A. I., Lazou, T., Bossis, I., & Gelasakis, A. I. (2020). Natural phenolic compounds for the control of oxidation, bacterial spoilage, and foodborne pathogens in meat. *Foods*, *9*(6), 1–28. https://doi.org/10.3390/foods9060794

Kammoun Bejar, A., Kechaou, N., & Mihoubi, N. B. (2011). Effect of Microwave Treatment On Physical and Functional Properties of Orange (Citrus Sinensis) Peel and Leaves. *Journal of Food Processing & Technology*, *02*(02). https://doi.org/10.4172/2157-7110.1000109

Karre, L., Lopez, K., & Getty, K. J. K. (2013). Natural antioxidants in meat and poultry products. *Meat Science*, *94*(2), 220–227. https://doi.org/10.1016/j.meatsci.2013.01.007

Kealey, K. S., & Kinsella, J. E. (1979). Orange juice quality with an emphasis on flavor components. *C R C Critical Reviews in Food Science and Nutrition*, *11*(1), 1–40. https://doi.org/10.1080/10408397909527258

Khan, S., Patel, A., & Bhise, K. S. (2017). Antioxidant Activity of Pomegranate Peel Powder. *Journal of Drug Delivery and Therapeutics*, *7*(2). https://doi.org/10.22270/jddt.v7i2.1380

KITA, A., FIGIEL, A., CARBONELL-BARRACHINA, A., & GWOGDZIOWSKA, M. (2009). Texture profile analysis (TPA) of hazelnuts under different thermal treatment. *International Agrophysics*, *23*(1), 39–43.

Knipe, L. (2003). EMULSIFIERS | Phosphates as Meat Emulsion Stabilizers.

Encyclopedia of Food Sciences and Nutrition, *1989*, 2077–2080. https://doi.org/10.1016/b0-12-227055-x/00402-8

Kondo, S., Kittikorn, M., & Kanlayanarat, S. (2005). Preharvest antioxidant activities of tropical fruit and the effect of low temperature storage on antioxidants and jasmonates. *Postharvest Biology and Technology*, *36*(3), 309–318. https://doi.org/10.1016/j.postharvbio.2005.02.003

Lario, Y., Sendra, E., García-Pérez, J., Fuentes, C., Sayas-Barberá, E., Fernández-López, J., & Pérez-Alvarez, J. A. (2004). Preparation of high dietary fiber powder from lemon juice by-products. *Innovative Food Science and Emerging Technologies*, *5*(1), 113–117. https://doi.org/10.1016/j.ifset.2003.08.001

Larrauri, J. A., Rupérez, P., Borroto, B., & Saura-Calixto, F. (1996). Mango peels as a new tropical fibre: Preparation and characterization. *LWT - Food Science and Technology*, *29*(8), 729–733. https://doi.org/10.1006/fstl.1996.0113

Law, P., Izidoro, D. R., Scheer, A. D. P., & Sierakowski, M. (2009). *Rheological Properties of Emulsions Stabilized by Green Banana (Musa Rheological Properties of Emulsions Stabilized by Green Banana (Musa cavendishii) Pulp Fitted by Power Law Model. November*. https://doi.org/10.1590/S1516-89132009000600026

Li, S., Lo, C.-Y., & Ho, C.-T. (2006). *Li2006*. 4176–4185.

Lindahl, G., Lundström, K., & Tornberg, E. (2001). Contribution of pigment content, myoglobin forms and internal reflectance to the colour of pork loin and ham from pure breed pigs. *Meat Science*, *59*(2), 141–151. https://doi.org/10.1016/S0309-

1740(01)00064-X

Lu, Y., & Yeap Foo, L. (2000). Antioxidant and radical scavenging activities of polyphenols from apple pomace. *Food Chemistry*, *68*(1), 81–85. https://doi.org/10.1016/S0308-8146(99)00167-3

M. Ibrahim, H., M. Hassan, I., & A.M. Hamed, A. (2018). Application of Lemon and Orange Peels in Meat Products: Quality and Safety. *International Journal of Current Microbiology and Applied Sciences*, *7*(04), 2703–2723. https://doi.org/10.20546/ijcmas.2018.704.309

Mahmoud, M. H., Abou-Arab, A. A., & Abu-Salem, F. M. (2017). Quality Characteristics of Beef Burger as Influenced by Different Levels of Orange Peel Powder. *American Journal of Food Technology*, *12*(4), 262–270. https://doi.org/10.3923/ajft.2017.262.270

Manthey, J. A., & Grohmann, K. (2001). Phenols in citrus peel byproducts. Concentrations of hydroxycinnamates and polymethoxylated flavones in citrus peel molasses. *Journal of Agricultural and Food Chemistry*, *49*(7), 3268–3273. https://doi.org/10.1021/jf010011r

McDonagh, C., Troy, D., Desmond, E., & McDermott, H. (2005). *Nutritional enhancement of meat products with dietary fibers*.

Meat and Livestock Australia, M. (2011). Tips P & Tools. *Beef*, 1–4.

Menezes, B. S., Zanette, B., Souza, J. T. A., Cortez-Vega, W. R., & Prentice, C. (2015). Comparison of physicochemical and functional properties of surimi and protein isolate obtained from mechanically deboned meat of chicken. *International Food Research Journal*, *22*(4), 1374–1379.

Moawad, R. K., & Bareh, G. F. (2014). *Quality Enhancement and Shelf-Life Extension of Raw Beef Patties Formulated with Lactate / Thyme Essential Oil during Refrigerated Storage*. *9*(13), 6699–6709.

Moure, A., Cruz, J. M., Franco, D., Manuel Domínguez, J., Sineiro, J., Domínguez, H., Núñez, M. J., & Carlos Parajó, J. (2001). Natural antioxidants from residual sources. *Food Chemistry*, *72*(2), 145–171. https://doi.org/10.1016/S0308-8146(00)00223-5

Nassar, A., & Sulaiman, A. M. (2016). *Phytochemical and Antioxidant Activity of Some Agriculture Waste as A Functional Food in Meat Technology*. 328–339.

Naveena, B. M., Sen, A. R., Kingsly, R. P., Singh, D. B., & Kondaiah, N. (2008). Antioxidant activity of pomegranate rind powder extract in cooked chicken patties. *International Journal of Food Science and Technology*, *43*(10), 1807–1812. https://doi.org/10.1111/j.1365-2621.2007.01708.x

Parashar, S., Sharma, H., & Garg, M. (2014). Antimicrobial and Antioxidant activities of fruits and vegetable peels: A review. *Journal of Pharmacognosy and Phytochemistry JPP*, *3*(31), 160–164.

Pathak, P. D., Mandavgane, S. A., & Kulkarni, B. D. (2017). Fruit peel waste: Characterization and its potential uses. *Current Science*, *113*(3), 444–454. https://doi.org/10.18520/cs/v113/i03/444-454

Pathare, P. B., Opara, U. L., & Al-Said, F. A. J. (2013). Colour Measurement and Analysis in Fresh and Processed Foods: A Review. *Food and Bioprocess Technology*, *6*(1), 36–60. https://doi.org/10.1007/s11947-012-0867-9

Pereira, A., & Maraschin, M. (2015). Banana (Musa spp) from peel to pulp: Ethnopharmacology, source of bioactive compounds and its relevance for human health. *Journal of Ethnopharmacology*, *160*, 149–163. https://doi.org/10.1016/j.jep.2014.11.008

Ren, W., Qiao, Z., Wang, H., Zhu, L., & Zhang, L. (2003). Flavonoids: Promising anticancer agents. *Medicinal Research Reviews*, *23*(4), 519–534. https://doi.org/10.1002/med.10033

Richard, L. (1995). Food Safety Hazards in Foodservice and Food Retail. *Department of Food Science Purdue University*, 10.

Ritchie, H., & Roser, M. (2017). *Meat and Dairy Production*. Our World in Data. https://ourworldindata.org/meat-production#global-meat-production

Rocha-Garza, A. E., & Zayas, J. F. (1996). Quality of broiled beef patties supplemented with wheat germ protein flour. *Journal of Food Science*, *61*(2), 418–421. https://doi.org/10.1111/j.1365-2621.1996.tb14207.x

Rosas-Burgos, E. C., Burgos-Hernández, A., Noguera-Artiaga, L., Kačániová, M., Hernández-García, F., Cárdenas-López, J. L., & Carbonell-Barrachina, Á. A. (2017). Antimicrobial activity of pomegranate peel extracts as affected by cultivar. *Journal of the Science of Food and Agriculture*, *97*(3), 802–810. https://doi.org/10.1002/jsfa.7799

Ross, J. A., & Kasum, C. M. (2002). Dietary flavonoids: Bioavailability, metabolic effects, and safety. *Annual Review of Nutrition*, *22*, 19–34. https://doi.org/10.1146/annurev.nutr.22.111401.144957

Rufenacht, B. (2020). *pH: It's pHundamental – Dairy Connection Blog*. https://www.dairyconnection.com/blog/2020/02/17/ph-why-its-important-to-you/

Sangnark, A., & Noomhorm, A. (2003). Effect of particle sizes on functional properties of dietary fibre prepared from sugarcane bagasse. *Food Chemistry*, *80*(2), 221–229. https://doi.org/10.1016/S0308-8146(02)00257-1

Sariçoban, C., Yilmaz, M. T., & Karakaya, M. (2009). Response surface methodology study on the optimisation of effects of fat, wheat bran and salt on chemical, textural and sensory properties of patties. *Meat Science*, *83*(4), 610–619. https://doi.org/10.1016/j.meatsci.2009.07.010

Savitri. (n.d.). *pH of Banana — Acidic or Alkaline?* Retrieved August 5, 2021, from https://techiescientist.com/ph-of-banana/

Schmidt, G., & Trout, G. (1984). *pH and Color*. *30*(8), 30–32.

Selani, M. M., Contreras-Castillo, C. J., Shirahigue, L. D., Gallo, C. R., Plata-Oviedo, M., & Montes-Villanueva, N. D. (2011). Wine industry residues extracts as natural antioxidants in raw and cooked chicken meat during frozen storage. *Meat Science*, *88*(3), 397–403. https://doi.org/10.1016/j.meatsci.2011.01.017

Sendra-nadal, E., Navarro, C., Sayas, E., Viuda-martos, M., Fema, J., & Pe, A. (2009). *Original article Storage stability of a high dietary fibre powder from orange*. 748–

756. https://doi.org/10.1111/j.1365-2621.2008.01892.x

Sharma, K., Mahato, N., Cho, M. H., & Lee, Y. R. (2017). Converting citrus wastes into value-added products: Economic and environmently friendly approaches. *Nutrition*, *34*, 29–46. https://doi.org/10.1016/j.nut.2016.09.006

Sharma, P., & Yadav, S. (2020). *Effect of Incorporation of Pomegranate Peel and Bagasse Powder and Their Extracts on Quality Characteristics of Chicken Meat Patties*. *40*(3), 388–400.

Sir Elkhatim, K. A., Elagib, R. A. A., & Hassan, A. B. (2018). Content of phenolic compounds and vitamin C and antioxidant activity in wasted parts of Sudanese citrus fruits. *Food Science and Nutrition*, *6*(5), 1214–1219. https://doi.org/10.1002/fsn3.660

Someya, S., Yoshiki, Y., & Okubo, K. (2002). Antioxidant compounds from bananas (Musa Cavendish). *Food Chemistry*, *79*(3), 351–354. https://doi.org/10.1016/S0308-8146(02)00186-3

Soyer, A., Ertaş, A. H., & Üzümcüoğlu, Ü. (2005). Effect of processing conditions on the quality of naturally fermented Turkish sausages (sucuks). *Meat Science*, *69*(1), 135–141. https://doi.org/10.1016/j.meatsci.2004.06.015

Springmann, M., Mason-D'Croz, D., Robinson, S., Wiebe, K., Godfray, H. C. J., Rayner, M., Scarborough, P., BMEL, Andhini, N. F., Sha, L., Xiong, Y. L., Özbaş, Ö. Ö., Ardiç, M., Kausar, T., Hanan, E., Ayob, O., Praween, B., Azad, Z., Elzerman, J. E., … Cartsburg, M. (2019). Nahrungsmittelverbrauch und Fußabdrücke des Konsums in Deutschland: Eine Neubewertung unserer Ressourcennutzung. *Trends in Food Science and Technology*, *15*(5), 62. http://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Studie_Nahrungsmittelverbrauch_und_Fussabduecke_des_Konsums_in_Deutschland.pdf%0Ahttps://doi.org/10.1016/j.tifs.2020.04.023%0Ahttp://dergipark.gov.tr/download/article-file/308568%0Ahttps://doi.org/l

Stephen. (2016). *Fertilize your Organic Garden for Free with Banana Peels – Alberta Urban Garden*. https://www.albertaurbangarden.ca/2016/02/05/fertilize-your-organic-garden-for-free-with-banana-peels/

Talukder, S., & Sharma, D. P. (2010). Development of dietary fiber rich chicken meat patties using wheat and oat bran. *Journal of Food Science and Technology*, *47*(2), 224–229. https://doi.org/10.1007/s13197-010-0027-z

Tighe-Neira, R., Alberdi, M., Arce-Johnson, P., Romero-Romero, J. L., Reyes-Díaz, M., & Inostroza-Blancheteau, C. (2017). Foods with Functional Properties and their Potential Uses in Human Health. *Superfood and Functional Food - An Overview of Their Processing and Utilization*, *July*. https://doi.org/10.5772/67077

Tornberg, E. (2005). Effects of heat on meat proteins - Implications on structure and quality of meat products. *Meat Science*, *70*(3 SPEC. ISS.), 493–508. https://doi.org/10.1016/j.meatsci.2004.11.021

Tungland, B. C., & Meyer, D. (2002). Nondigestible oligo-and polysaccharides (dietary fiber): Their physiology and role in human health and food. *Comprehensive Reviews* *in Food Science and Food Safety*, *1*(3), 90–109. https://doi.org/10.1111/j.1541-4337.2002.tb00009.x

University of Michigan Health. (2020). *Minerals:Their functions and sources*. https://www.uofmhealth.org/health-library/ta3912

VELP Scientifica. (2013). *APPLICATION NOTE Determination of the Total Volatile Basic Nitrogen (TVBN) in Fish according to Conway and Byrne method*. *1933*, 2. https://researchoutput.csu.edu.au/en/publications/total-volatile-basic-nitrogen-tvb-n-and-its-role-in-meat-spoilage

Vinci, G., & Antonelli, M. L. (2002). Biogenic amines: Quality index of freshness in red and white meat. *Food Control*, *13*(8), 519–524. https://doi.org/10.1016/S0956-7135(02)00031-2

Viuda-Martos, M., Ruiz-Navajas, Y., Martin-Sánchez, A., Sánchez-Zapata, E., Fernández-López, J., Sendra, E., Sayas-Barberá, E., Navarro, C., & Pérez-Álvarez, J. A. (2012). Chemical, physico-chemical and functional properties of pomegranate (Punica granatum L.) bagasses powder co-product. *Journal of Food Engineering*, *110*(2), 220–224. https://doi.org/10.1016/j.jfoodeng.2011.05.029

Warner, R. (2014). Measurements of Water-holding Capacity and Color: Objective and Subjective. *Encyclopedia of Meat Sciences*, *January 2014*, 164–171. https://doi.org/10.1016/B978-0-12-384731-7.00210-5

Yadav, S., Pathera, A. K., Islam, R. U., Malik, A. K., & Sharma, D. P. (2018). Effect of wheat bran and dried carrot pomace addition on quality characteristics of chicken sausage. *Asian-Australasian Journal of Animal Sciences*, *31*(5), 729–737. https://doi.org/10.5713/ajas.17.0214

Yarmand, M. S., Nikmaram, P., Emam Djomeh, Z., & Homayouni, A. (2013). Microstructural and mechanical properties of camel longissimus dorsi muscle during roasting, braising and microwave heating. *Meat Science*, *95*(2), 419–424. https://doi.org/10.1016/j.meatsci.2013.05.018

Youssef, M. K., & Barbut, S. (2011). Fat reduction in comminuted meat products-effects of beef fat, regular and pre-emulsified canola oil. *Meat Science*, *87*(4), 356–360. https://doi.org/10.1016/j.meatsci.2010.11.011

Zaini, H. B. M., Sintang, M. D. Bin, & Pindi, W. (2020). The roles of banana peel powders to alter technological functionality, sensory and nutritional quality of chicken sausage. *Food Science and Nutrition*, *8*(10), 5497–5507. https://doi.org/10.1002/fsn3.1847

Zuhaib, F. ., Pathak, V., & Hina, F. (2013). Effect of refrigerated storage on the quality characteristics of microwave cooked chicken seekh kababs extended with different non-meat proteins. *Journal of Food Science and Technology*, *50*(5), 926–933. https://doi.org/10.1007/s13197-011-0410-4

APPENDICES

5.3 pH analysis

Appendix 1 pH analysis

Sample	pH value
Control	8.24
Control	8.33
1%BPF	8.17
1%BPF	8.16
2%BPF	7.98
2%BPF	7.89
3%BPF	7.79
3%BPF	7.77
1%PPF	7.39
1%PPF	7.38
2%PPF	7.21
2%PPF	7.19

3%PPF	6.97
3%PPF	6.94
1%OPF	8.16
1%OPF	8.15
2%OPF	7.25
2%OPF	7.23
3%OPF	5.95
3%OPF	5.89

5.4 Cooking properties

Appendix 2 Cooking properties

Sample	Cooking Yield (%)	Cooking Loss (%)	Shrinkage
Control	69.9930	30.0070	20.0000
Control	69.5221	30.4779	18.8235
1%BPF	77.8368	22.1632	15.2941
1%BPF	77.6736	22.3264	16.4706

2%BPF	80.1262	19.8738	1.1765
2%BPF	80.1870	19.8130	3.5294
3%BPF	75.8474	24.1526	3.5294
3%BPF	76.0017	23.9983	2.3529
1%PPF	75.7329	24.2671	11.7647
1%PPF	75.0275	24.9725	15.2941
2%PPF	78.0186	21.9814	1.1765
2%PPF	77.8612	22.1388	2.3529
3%PPF	73.5002	26.4998	11.7647
3%PPF	73.0484	26.9516	11.7647
1%OPF	74.6147	25.3853	11.7647
1%OPF	74.1545	25.8455	15.2941
2%OPF	73.8092	26.1908	2.3529
2%OPF	72.2712	27.7288	1.1765
3%OPF	78.0705	21.9295	15.2941
3%OPF	77.4221	22.5779	18.8235

5.5 WHC and OHC analysis

Appendix 3 WHC and OHC analysis

Sample	WHC	OHC
Control	0.85588	0.361765
Control	0.83627	0.262745
1%BPF	1.54314	0.586275
1%BPF	1.56667	0.579412
2%BPF	1.73922	0.718627
2%BPF	1.66569	0.715686
3%BPF	1.49314	0.753922
3%BPF	1.53824	0.785294
1%PPF	1.06667	0.476471
1%PPF	1.08529	0.515686
2%PPF	1.35980	0.458824
2%PPF	1.35784	0.441176

3%PPF	1.11765	0.741176
3%PPF	0.96275	0.679412
1%OPF	0.95392	0.543137
1%OPF	1.00294	0.413725
2%OPF	1.35882	0.439216
2%OPF	1.24510	0.607843
3%OPF	1.13725	0.534314
3%OPF	1.15000	0.620588

5.6 Color analysis

Appendix 4 Color analysis

Sample	L*	a*	b*	$\Delta E*$
Control	37.94	2.07	4.58	61.8753
Control	38.12	2.99	5.01	61.7694
1%BPF	37.90	1.07	2.24	61.7504
1%BPF	37.50	1.99	3.09	62.2131

2%BPF	29.30	0.90	0.22	70.2978
2%BPF	30.20	1.65	0.07	69.4111
3%BPF	29.13	0.62	-0.50	73.4633
3%BPF	30.13	0.53	-1.50	70.4731
1%PPF	37.90	3.53	5.610	61.7454
1%PPF	37.50	4.89	2.456	60.8317
2%PPF	36.45	2.11	3.350	64.2771
2%PPF	35.11	3.01	2.800	63.6259
3%PPF	34.30	0.93	2.920	66.3732
3%PPF	33.24	1.99	2.010	65.4306
1%OPF	38.50	1.62	3.180	60.6271
1%OPF	37.50	2.12	5.990	61.5446
2%OPF	34.67	1.92	6.970	63.3026
2%OPF	43.65	2.31	6.776	64.4197
3%OPF	34.71	2.34	6.550	59.8125
3%OPF	45.17	3.11	7.880	61.2912

5.7 Texture Analysis

Appendix 5 Texture analysis

Sample	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness
Control	215.74	49.11	0.977000	210.778	10351.3
Control	205.98	41.57	0.913682	188.200	7823.5
1%BPF	345.11	20.99	0.909366	313.831	6587.3
1%BPF	322.81	30.49	0.942100	304.119	9272.6
2%BPF	354.11	36.66	0.912130	322.994	11841.0
2%BPF	339.93	29.18	0.847154	287.973	8403.1
3%BPF	375.86	37.65	0.886110	333.053	12539.5
3%BPF	401.44	28.19	0.795642	319.403	9004.0
1%PPF	414.76	22.16	0.954670	395.959	8774.4
1%PPF	446.80	33.64	0.869600	388.537	13070.4
2%PPF	437.16	39.49	0.766694	335.168	13235.8
2%PPF	402.84	26.23	0.986846	397.541	10427.5

3%PPF	421.77	27.39	0.889470	375.152	10275.4
3%PPF	386.23	36.17	0.808788	312.378	11298.7
1%OPF	297.62	20.69	0.899610	267.742	5539.6
1%OPF	306.88	30.85	0.851814	261.405	8064.3
2%OPF	633.33	24.99	1.004364	636.094	15896.0
2%OPF	592.51	31.93	0.859006	508.970	16251.4
3%OPF	180.65	23.88	1.226710	221.605	5291.9
3%OPF	155.09	29.88	0.723080	112.142	3350.8

5.8 Sensory Evaluation

Appendix 6 Sample copy of sensory evaluation

Sensory Evaluation

Name: Ida Syariza binti Kamaruddin

Department: KPM

Date: 6/7/2021

The evaluations were assessed by using the 9 point scale where the parameters include colour, taste, odour, texture, and overall acceptability. The scale are as below: Please do answer in number from scale 1-9.

Score	1-3	4-6	7-9
Description	Like slightly	Like moderately	Like very much

Samples	Appearance	Colour	Taste	Odour	Texture	Overall acceptability
A	7	8	9	7	5	7
B	5	4	6	7	4	5
C	4	5	8	8	6	6
D	4	3	3	5	4	5
E	8	5	8	6	6	7
F	7	6	5	6	4	6
G	5	4	4	6	4	4
H	8	7	7	9	8	8
I	8	8	5	9	5	5
J	4	3	2	8	4	3