UTILIZATION OF PURPLE EGGPLANT FLOUR IN LOW FAT BEEF PATTIES

PIYANART NUNTALIT

A Thesis Submitted to University of Phayao

in Partial Fulfillment of Requirements

for the Master of Science in Animal Science

September 2020

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วิทยานิพนธ์เสนอมหาวิทยาลัยพะเยา เพื่อเป็นส่วนหนึ่งของการศึกษา
หลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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Approved in partial fulfillment of the requriements for the

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Title: UTILIZATION OF PURPLE EGGPLANT FLOUR IN LOW FAT BEEF PATTIES

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Keyword Beef patties, Purple eggplant, Dietary fiber, Antioxidant

ABSTRACT

The purpose of this study was to determine the effects of reducing pork fat levels by partially substituting pork fat with purple eggplant flour (PEF) (0, 2.5, 5 and 7.5%) on nutritional composition, water holding capacity (WHC), cooking loss, cooking quality, textural properties, sensory evaluations, color and lipid oxidation of low fat beef patties during refrigerated storage. The results showed that the addition of PEF increased ($P<0.05$) the moisture and ash contents in low fat beef patties, whereas it decreased the fat and protein content compared to the control sample. Beef patties prepared with PEF exhibited lower thawing loss, drip loss, cooking loss, diameter and thickness, while the cooking yield, moisture and fat retention increased with increasing PEF levels ($P<0.05$). The different levels of PEF had no significant effect on texture, but the shear force was significantly higher than control sample. All the sensory attributes of all treatments were not significantly different. The color values of the beef patties decreased gradually with the storage time. PEF incorporated beef patties showed L* and a* values lower than control samples ($P<0.05$). TBARS values of control samples were higher than that of samples with PEF at the end of the storage period (7 days). The results of this study show that adding PEF successfully reduced fat in beef patties, while improving quality characteristics.

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my greatest appreciation to all individuals who have helped and supported me throughout the project. I am thankful to my advisor (Dr.Thanaporn Boonmee) for her ongoing support during the project. Her suggestions and instructions have served as the major contributor towards the competition of this project. Then I would like to thank co-advisor for their continued support and encouragement: Dr. Niraporn Chaiwang and Dr. Thanikarn Sansawat. I offer my sincere appreciation for the learning opportunities provided by my co-advisor.

I would also like to thank my family and my friends for constantly encouraging me during the course of this project, which I could not have completed without their support and continuous encouragements.

My completion of this project could not have been accomplished without the support from the people I mentioned before.

Piyanart Nuntalit

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CHAPTER I

INTRODUCTION

The economy, politics and social globalization affects consumer behavior. Therefore, manufacturers must pay attention and have appropriate strategies to fulfill the needs of consumers. In the present, meat patty or hamburger is becoming popular worldwide because it is ready to cook, convenient, reasonably priced and economical for a busy lifestyle but some consumers concern about the quality of burger because this product has been considered as one of the unhealthy foods. It contains high unsaturated fatty acids, calories and salt, and may put people at risk for becoming overweight, cardio–vascular diseases and hypertension. Moreover, meat products are very susceptible to oxidation. The oxidation of lipids is one of the major causes of deterioration in the quality of meat and meat products. Furthermore, lipid oxidation products initiate the oxidation of protein leading to serious health concerns (Falowo, Fayemi and Muchenje, 2014). The incorporation of dietary fiber in low fat meat products has been suggested to reduce the saturated fat level and also to increase the yield, fiber and water content of the final product (Talukder, 2015). Besides, high dietary fiber foods are associated with lowering blood pressure, lowering incidence of obesity and increasing satiety as well as reducing the risks of gastrointestinal disease, hypercholesterolemia, colorectal cancer and constipation (Anderson et al., 2009).

Researchers at the US Agricultural Service in Beltsville, Maryland, have found that eggplants are rich sources of phenolic compounds that function as antioxidants. Eggplant is low in calories and high in fiber, mineral and anthocyanin content beneficial for human health. Therefore, research on purple eggplant has focused on an anthocyanin phytonutrient found in purple eggplant skin. Anthocyanins are groups of water soluble pigments which can act as antioxidants or free radical scavengers, thus preventing oxidative stress (Brito et al., 2014). Antioxidants increase the stability of food components, especially polyunsaturated lipids, prevent degradation, discoloration, oxidative rancidity and maintain the initial and preferred sensory properties.

Objectives

1. To determine the effects of using different levels of purple eggplant flour on the nutritional value of beef patties.

2. To determine the effects of using different levels of purple eggplant flour on product quality and sensory quality of beef patties.

3. To determine the effects of using different levels of purple eggplant flour and storage time on storage stability of beef patties.

Hypothesis

Purple eggplant flour can improve the nutritional value, sensory quality, product quality, storage stability and extend product shelf life of beef patties.

Scope of the Research

This research focuses on the effect of using different levels of purple eggplant flour on the nutritional value, storage stability, sensory and product quality of beef patties.

Expected Benefits

1. To obtain beef patties enriched with nutrition to increase value add of beef patties for responding to people who concern with health.

2. To obtain beef patties with better sensory and product qualities.

3. To obtain beef patties enriched with anthocyanin which can retard or prevent lipid oxidation and extend shelf life in beef patties.

CHAPTER II

REVIEW OF RELATED LITERATURE AND RESEARCH

Introduction

The busy and hectic life schedule has opened the way for the fast–food industry in most parts of the world. The traditional or conventional way of cooking becomes less popular and the fast–food joints are visible everywhere (Darwish, 2018). Fast food refers to food that can be served ready to eat fast. The most famous fast–food items are hamburger, shawarma and pizza (Darwish, 2018). Fast food is popular because it is inexpensive, convenient and tastes good. Fast food is often made of cheap ingredients such as high fat meat, refined grains and added sugar or fats, instead of nutritious ingredients such as lean meats, whole grains, fresh fruits and vegetables.

Ready–to–Eat (RTE) meat products are growing in popularity because meat products are important sources of proteins, vitamins and minerals, but they also contain saturated fatty acids, cholesterol and salt (Hathwar et al., 2012). However, many studies started showing how cardiovascular problems, diabetes, cancers and obesity, all diseases related to poor eating habits, were drastically on the increase. Soon food producers had to face a new challenge: awareness about healthy nutrition, the slogan "you are what you eat" became more and more representative of the people's new mindset. However, whilst people wanted to consume food with no fat, it was actually the fat that gave it flavor and so, once it was removed, the consumer no longer found it attractive (Recordati, 2015).

Meat and meat composition

Muscle cells are among the most highly organized cells in the animal body and perform varied array of mechanical functions. They are required for the movement and they must also perform finer tasks such as maintaining balance and coordination. All of these functions depended on cellular metabolism and the ability of the cell to maintain energy supplies. The ability of living skeletal muscle to undergo relatively large intracellular changes also influences its response to the drastic alterations that occur during the first

few hours following exsanguination. Thus, the organization, structure and metabolism of the muscle are keys to its function and to the maintenance of its integrity both during contraction and during the early postmortem period. Ultimately, these postmortem changes will influence the suitability of meat for further processing (Huff–Lonergan, 2010).

Nutritional value of meat

Meat has an important role in human nutrition because of its nutritive value, which is measured in terms of the major chemical components such as protein, carbohydrate, fat, fatty acids and mineral (Ortega–Barrales and Fernández-de Córdova, 2015) The largest constituent of muscle is water (Table 1 Composition of Mammalian Muscle). In living tissue, the average water content is 75% of the weight of the muscle; however, can vary, particularly in postmortem muscle (range of 65 to 80%). Within the muscle, it is the primary component of extracellular fluid. Within the muscle cell, water is the primary component of sarcoplasmic (cytoplasmic) fluid. It is important in thermoregulation; as a medium for many cellular processes; and for transport of nutrients within the cell, between cells and between the muscle and the vascular system (Huff–Lonergan, 2010).

Table 1 Composition of Mammalian Muscle

Component	% of Muscle Weight
Water	75% (65 – 80%)
Protein	18.5% (16 – 22%)
Lipid	3% (1 – 13%)
Carbohydrate	1% (0.5 – 1.5%)
Non–Protein Nitrogenous Substances	1.7% (1 – 2%)
Other Non–Protein Substances (minerals, vitamins, etc.)	0.85% (0.5 – 1%)

Note: Numbers in parentheses indicate the average range of that component.

Source: USDA: United States Department of Agriculture (2008)

1. Protein

Protein is the second largest component of muscle (USDA: United States Department of Agriculture, 2008) Protein makes up an average of 18.5% of the weight of the muscle. Protein serves numerous functions and is the primary solid component in muscle. Muscle protein is involved in maintaining the structure and organization of the muscle and muscle cells. It is also important in the contractile process. These proteins primarily are associated with the contractile organelles, the myofibril and are thus termed myofibrillar proteins. This class of proteins includes both the proteins directly involved in movement (contractile proteins) and proteins that regulate the interactions between the contractile proteins (regulatory proteins). There are also many soluble proteins (sarcoplasmic proteins) that include proteins involved in cellular signaling processes and enzymes important in metabolism and protein degradation/cellular remodeling.

2. Lipid and fatty acid

The lipid content of the muscle can vary greatly due to many factors, including animal age, nutritional level of the animal and muscle type. It is important to note that the lipid content varies inversely with the water content. Some lipid is stored inside the muscle cell; however, within a muscle, the bulk of the lipid is found between muscle bundles (groupings of muscle cells). Average lipid content of skeletal muscle is about 3% of the muscle weight, but the range can be as much as 1 to 13% (USDA: United States Department of Agriculture, 2008). In skeletal muscle, lipid plays roles in energy storage, membrane structure and in various other processes in the organ, including immune responses and cellular recognition pathways.

The two major types of lipid found in skeletal muscle are triglycerides and phospholipids. Triglycerides make up the greatest proportion of lipid associated with muscle. Triglycerides (triacylglycerides) consist of a glycerol molecule in which the hydroxyl groups are esterified with three fatty acids. The melting point and the iodine number of lipids that is associated with the muscle is determined by the chain length and the degree of saturation of the fatty acids. Phospholipids (phosphoglycerides) are another type of complex lipid found in muscle. In this class of lipids, one of the hydroxyl groups of glycerol is esterified to a phosphate group, while the other constituents are fatty acids. The fatty

acids associated with phospholipids are typically unsaturated. Phospholipids in skeletal muscle are commonly associated with membranes. The relative high degree of unsaturation of the fatty acids associated with the phospholipids is a contributing factor to the fluidity of the cell membranes.

3. Carbohydrate

Carbohydrates make up a relatively small percentage of muscle tissue, making up about 1% of the total muscle weight (range of 0.5 to 1.5%). The carbohydrate that makes up the largest percentage is glycogen. Other carbohydrate includes glucose, intermediates of glycogen metabolism and other mono- and di-saccharides. Glycosaminoglycans are also found in muscle and are associated with the connective tissue (Huff-Lonergan, 2010).

4. Minerals

Minerals are transferred through the food chain to animals and humans and meat is one of the major sources of elements such as iron, phosphorus, zinc and selenium in the diet. Some of these minerals considered as essential elements with well-defined physiological functions, are present exclusively in meat or their bioavailability is much higher than that from vegetables. The concentration of the minerals in animal tissues depends mainly on the species of animal, the dietary concentration of the element, the absorption of the element and the concentration of other tissue minerals (Ortega-Barrales and Fernández-de Córdova, 2015).

Burger

Controversy arises when the origin of burgers and meat patties is discussed. While some say that people in Eastern Europe eating tartare (a food product containing finely minced very lean beef mixed with raw egg and eaten raw on bread) were the inventors of the burger, most people agree that the first hamburger was invented in the USA (Feiner, 2006).

In the USA, terms such as ground beef or chopped beef are synonymous. However, the term ground beef refers in most other countries to minced meat only and has nothing in common with a hamburger or any formed product made from minced meat.

Generally, ground beef in the USA is produced from fresh and/or frozen beef with or without seasoning. The fat content must not exceed 30%. Ground beef must also not contain added water and no fillers such as starch or flour are allowed. Frequently, beef cheek meat is incorporated into ground beef at levels of up to 25%. When certain cut of meat such as topside is utilized for the production of ground beef, the product can be labeled "ground beef topside" and all meat utilized must then originate from topside. Because certain cuts of beef are very lean, beef fat is often introduced and the final product is then called "ground beef, beef fat added" (Feiner, 2006).

Burgers and patties are produced in endless different ways with regard to types of meat utilized, form, shape, nutritional value, cost considerations, as well as religious reasons. In the USA and several other countries, the term "hamburger" is generally associated only with burgers made with processed beef. However, products called hamburgers produced from turkey and other types of meat are produced in other parts of the world. Whilst some burgers consist of minced beef, with some salt and spices, others are mix of minced meat and salt without any spices whatsoever. Some "pure-beef" burgers are made of beef meat only without any salt, spices or added water, resulting in a crumbly texture preferred by some consumers. Other types of burger commonly contain, besides meat and fat, small amounts of added water as well as additives such as salt, phosphates, spices and flavor enhancers. As an extension of a burger, a patty is generally 'the poor man's burger' and contains, besides the usual ingredients of a burger, elevated levels of water as well as additives such as protein, bread crumbs and/or starch. The quality of a burger, or patty alike, is to a great extent determined by the willingness of the consumer to pay for 'quality'. The quality or sensory properties of a burger or patty depend on parameters such as the animal breed from which the meat originates, the cut of the carcass utilized, the age of the animal, the pH value of meat to be processed, the diameter of the blades used during mincing, the forming systems in place and, especially, the level of non-meat ingredients within the burger or patty mass itself. Burgers and patties are now mostly stored frozen and are cooked (usually by grilling or frying) from frozen (Feiner, 2006).

Beef patty

Quality of beef patties depends on factors associated with the production. A typical recipe of medium to high quality would include 55 to 60% beef of 85% chemically lean (CL) grade and 40% beef of 50% CL grade. The water of 8 to 10% is added as well as 0.3 to 0.5% salt and 0.2% phosphate. Commonly, soy protein is also introduced at around 1% to stabilize fat during frying. Flavor or spices are frequently part of the recipe as well. Semi frozen meat and fat materials are commonly minced with a coarse blade (20 mm) first before being placed into a mixing machine. Salt, spices (pepper, garlic and onion) and phosphate are added and all ingredients mixed for around 30s. Iced water and soy protein are added and mixed continuously for around 2 min. At this stage, some degree of tackiness and shine is seen within and on the mixed meat mass. The tacky meat mass is subsequently minced with the desired blade (3 to 4 mm) and cooled with the help of carbon dioxide (CO_2) to around –2°C prior to forming for a clean knock–out. Occasionally, the temperature of the mixed mass prior to the second mincing is around –4°C and a temperature of around –2°C is obtained after mincing. As a result, the introduction of CO_2 prior to forming is not required. The formed product is IQF frozen, packed into bags with a predetermined number of patties and most often vacuum packed. Bags are placed into cartons and the product is stored at temperatures of around –20°C (Feiner, 2006).

Consumer concern

In the course of just one generation, food consumption habits and preferences have changed to a great extent. Children raised in the 1970s and 1980s regularly ate foods made from processed mixes, such as Kraft Macaroni and Cheese and Wonder bread. They enjoyed eating at fast food restaurants. In the winter months, their vegetables mostly came from a freezer or can. Children preferred pizza, burgers and hot dogs. Now parents themselves, these consumers do not want to serve the same highly processed foods to their own children. They serve organic foods if they can afford to do so. They want to offer healthier foods with “clean labels” that have a short list of ingredients and lower sodium. They try to steer clear of processed foods in general. They want greater control and are concerned with what is in their foods, the processes with which the foods are made and

where the ingredients are from. They are bored by their parents' bland diets and enjoy exploring foods from different nationalities. There is an increasing desire for variety, taste and local products (McCluskey, 2015).

Lipid oxidation in meat and meat products

Lipid oxidation represents one of the most important causes of quality deterioration during the storage in meat and meat products. Oxidative deterioration of lipids directly effects of flavor, color, texture, nutritional value and acceptability in meat. Here are also some other detrimental effects regarding lipid oxidation, including decrease of shelf life, increase of off–flavor, change of the functional and sensory characteristics and sometimes formation of carcinogenic substances food (Cheng, 2016). Malonaldehyde, which is a degradation product of lipid oxidation, has been criticized as a carcinogenic factor in food (Cheng, 2016). The high degree of susceptibility of animal fat to oxidation in such products is due to a variety of factors: the relatively high proportion of polyunsaturated fatty acids (PUFA) as constituents of membrane phospholipids, the deficiency of endogenous antioxidants, such as tocopherols, when compared with vegetable and other plant oils, high concentrations of prooxidants and radical initiators, such as heme species, high concentrations of salt (NaCl) added and the abundance of molecular oxygen that is usually incorporated into blended meats during processing operations (Jiang and Xiong, 2016).

Mechanism of Lipid Oxidation in Meat and Meat Products

Lipid oxidation is described as an oxygen–dependent, oxidative deterioration of saturated and unsaturated fatty acids. This modification of fatty acid is principally carried out by an autocatalytic mechanism of free radicals, called auto–oxidation and consisting of 3 phases: initiation, propagation and termination. In the 1st reaction, the presence of prooxidants (P_0), or reactive oxygen species (ROS), or any other oxidation–favorable condition, results in the loss of a hydrogen radical from unsaturated fatty acids. In the absence of such oxidation–favorable conditions, the reaction between fatty acids and oxygen molecules cannot occur because of the unequal electronic state and spin barrier posed by these ground states. Thus, the ROS or other P_0, after thermal, redox, or light reaction can produce free radicals and thus starts the primary reaction of lipid oxidation.

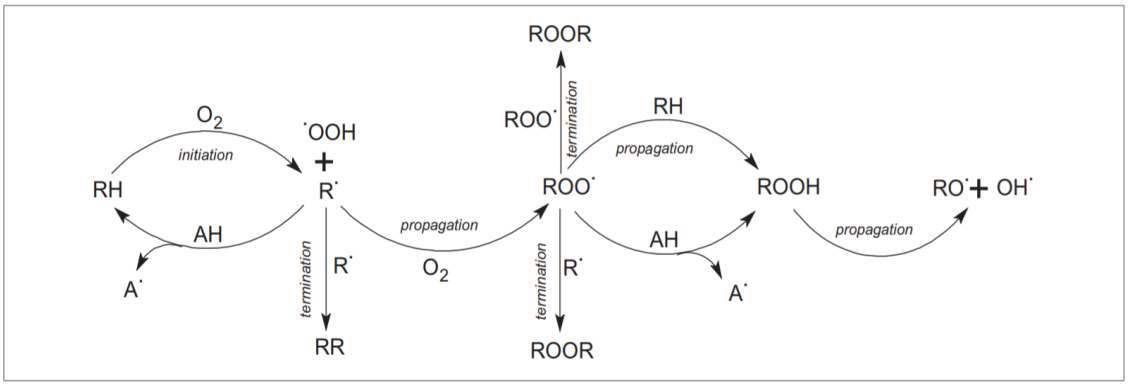

Figure 1 Mechanism of lipid oxidation; AH, antioxidant (free radical scavenger; chain breaking inhibitors); A·, scavenger radical (relatively very stable)

Source: Kumar et al. (2015)

In the 2nd stage, molecular oxygen reacts with the alkyl radical of an unsaturated fatty acid and results in peroxide radical formation (Figure 1). In a subsequent reaction, the formation of hydroperoxides occurs. These are primary products of lipid oxidation and are relatively stable at moderate reaction conditions (low temperature/absence of pro–oxidative metal ions). However, because of the adverse conditions present in the muscle foods the hydroperoxides become susceptible to further free radical chain reactions, such as isomerization and decomposition. This produces the secondary products, including pentanal, hexanal, 4–hydroxynonenal and malondialdehyde (MDA).

The last stage is known as termination reaction, during which the free radicals react in various combinations to form stable products. Other unstable compounds are also formed during the termination reaction, which also affect the quality of meat products and give rise to an unpleasant flavor (taste and odor).

Lipids and their derivative fatty acids are present in muscles as structural components of muscle membranes, as storage droplets of triacylglycerol between muscle fibers and as adipose tissue. The form and nature of these fatty acids decide color stability, drip loss and the development of oxidative rancidity, which ultimately decide the sensory and nutritional quality of meat products. The attractiveness of meat to the

purchaser is mainly related to color and flavor, after perceived economic value. When meat ages it turns brown as the myoglobin is converted to metmyoglobin. This is the main cause of rejection of meat and meat products by consumers. Lipid oxidation increases the rate of metmyoglobin formation; metmyoglobin acts as a catalyst for lipid oxidation, which further increases the rate of lipid oxidation and deterioration of product color and flavor occurs. Lipid oxidation also depends upon: the degree of unsaturation of the fatty acids; the level of antioxidants (internal or external); and the presence of prooxidants (P_0), such as free iron. The lipid oxidation rate is directly proportional to the unsaturation of fatty acids, which ultimately decides the color and oxidative stability of meat products.

There are 3 stages where lipid oxidation can take place: at preslaughter (live muscle), during slaughtering (conversion of muscle to meat) and after slaughtering (processing and storage) (Figure 2). In live animals, intrinsic factors are available that can control the oxidation reaction in muscular tissues, such as enzymes (superoxide dismutase, catalase and so on) and certain proteins and their mechanisms (transport proteins), or oxidative reaction breaking antioxidants (vitamin E and C). After slaughtering, these factors lose their antioxidative potential due to various post–slaughter conditions, such as anaerobic environment, presence of prooxidants (P_0) and lack of enzymatic antioxidative mechanisms. Hemoglobin and myoglobin, which are also considered as prooxidants, along with other processing parameters, result in lipid oxidation during processing and storage of meat and meat products (Kumar et al., 2015).

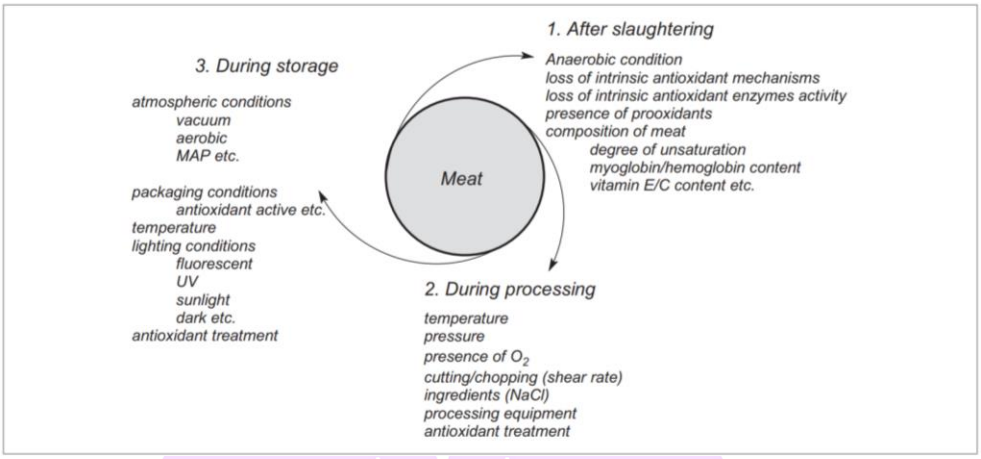

Figure 2 Factors affecting the oxidative stability of meat at various stages

Source: Kumar et al. (2015)

Antioxidants

Antioxidants must work in low concentration such as 200 to 500 ppm per kilogram of meat product, should demonstrate good solubility in fat or fatty material, must be non–toxic and also must not change or alter the taste of the meat product itself. Antioxidants in meat products have the primary task of deactivating or neutralizing free radicals to slow down the development of rancidity. More specifically, antioxidants extend the period of time until a significant number of oxidation related substances are formed and rancidity is observed. Deactivating peroxides is a secondary function of antioxidants and of far less importance. Antioxidants can block radicals, which are substances with a lone pair of electrons and therefore "negatively" charged, by donating hydrogen atoms and stabilize such radicals. Most antioxidants become radicals themselves by donating hydrogen atoms but are significantly less reactive and quite stable compared with radicals obtained from autoxidation. As a result of deactivating radicals, less hydrogen peroxide is formed, which can react to form substances such as aldehydes as well as ketones and therefore contribute to the rancid flavor and taste. Ascorbic acid also acts as an oxygen scavenger at the same time and therefore deactivates oxygen which is otherwise utilized, firstly, for the formation of peroxide and secondly for breaking bonds on double linkages in unsaturated fatty acids, leading to the formation of radicals (Feiner, 2006).

Synthetic antioxidants

Although the use of antioxidants dates back to ancient times when herbs and spices were used in food preservation, modern antioxidant technology is only about 60 years old. Since free radicals were found to be responsible for lipid oxidation, hundreds of natural and synthetic compounds have been evaluated for their efficacy as radical scavengers or for their other inhibitory effects. Among them, only four synthetic antioxidants are widely used in foods; namely, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG) and tert–butylhydroquinone (TBHQ). Scientists are attempting to develop novel synthetic antioxidants aimed at retarding the effects of free radical induced damage in various food products as well as in the human body cells. Synthetic antioxidants used in the food industry can be added as direct additives or indirectly through diffusion from packaging material.

All antioxidants have points of strengths and weaknesses. Therefore, certain points, such as thermal stability, effective concentration and synergism should be taken into consideration when selecting antioxidants for use in particular foods. Regulatory status is another factor that cannot be ignored, especially for some antioxidants that have been reported to show potential adverse health effects. Synthetic antioxidants have been tested for safety and approval for use in food at low concentrations on the basis of complex toxicity studies. Allowable limits for use of antioxidants vary greatly from country to country and depend on the food product under consideration.

Natural Antioxidants

Food tissues, because they are (or were) living, are under constant oxidative stress from free radicals, reactive oxygen species and pro–oxidants generated both exogenously (heat and light) and endogenously (H_2O_2 and transition metals). For this reason, many of these tissues have developed antioxidant systems to control free radicals, lipid oxidation catalysts, oxidation intermediates and secondary breakdown products. These antioxidant compounds include flavonoids, phenolic acids, carotenoids and tocopherols that can inhibit Fe^{3+}/AAinduced oxidation, scavenge free radicals and act as reductants.

Spices and herbs used in foods for their flavor and in medicinal mixtures for their physiological effects, often contain high concentrations of phenolic compounds that have

strong H–donating activity. Many also have high ORAC values (Table 2). Some plant derived compounds (carnosol, rosmanol, rosmariquinone and rosmaridiphenol) are better antioxidants than BHA (M. Brewer, 2011).

Table 2 Total ORAC values (μm TE/100 g) of selected herbs and spices, berries, roots and teas

Food	Total ORAC	SEM
Basil (fresh)	4805	225
Marjoram (fresh)	27297	1306
Oregano (fresh)	13970	545
Sage (fresh)	32004	1548
Savory (fresh)	9465	436
Basil (dried)	61063	2280
Cinnamon (ground)	131420	13867
Clove (ground)	290283	3292
Ginger (ground)	39041	1835
Nutmeg (ground)	69640	6859
Oregano (dried)	175295	7683
Pepper, black	34053	289
Rosemary (dried)	165280	1391
Sage (ground)	119929	20305
Thyme (fresh)	27426	1251
Thyme (dried)	157380	1629
Turmeric (ground)	127068	11181
Grapes (red, raw)	1837	248
Raspberries (raw)	5065	205
Garlic (raw)	5708	475
Ginger root (raw)	14840	530
Onions, red (raw)	1521	69
Tea brewed	1128	–

Table 2 (cont.)

Food	Total ORAC	SEM
Tea, green, brewed	1253	–

Note: The oxygen radical absorbance capacity (ORAC) method is based on the inhibition of the peroxyl–radical–induced oxidation initiated by thermal decomposition of azo compounds. Prior (2003) used 2,2' –azo bis (2 amidino propane) dihydrochloride (AAPH) as the azo generator, incubated at 37°C for 30 min with fluorescein (14 μm) as a fluorescent detector.

Source: M. Brewer (2011)

The common characteristic of the flavonoids (flavones, flavonols, flavanols and flavanones) is the basic 15–carbon flavan structure ($C_6C_3C_6$). These carbon atoms are arranged in 3 rings (A, B and C). Classes of flavonoids differ in the level of saturation of the C ring. Individual compounds within a class differ in the substitution pattern of the A and B rings that influence the phenoxyl radical stability and the antioxidant properties of the substances (M. Brewer, 2011).

The free radical–scavenging potential of natural polyphenolic compounds appears to depend on the pattern (both number and location) of free –OH groups on the flavonoid skeleton. The B–ring substitution pattern is especially important to free radical–scavenging ability of flavonols.

Flavonoids with multiple hydroxyl groups are more effective antioxidants than those with only one. The presence of the ortho 3,4–dihydroxy structure increases the antioxidative activity. Flavonoids can dampen transition metal enhancement of oxidation by donating a H^+ to them, rendering them less pro–oxidative. In addition, flavones and some flavanones (naringenin) can preferentially bind metals at the 5–hydroxyl and 4–oxo groups.

Evaluating the antioxidative activity of hydroxycinnamic acids with similar structures (caffeic, chlorogenic, o–coumaric and ferulic acids) in a fish muscle system, Medina et al. (2007) found that the capacity of these compounds to donate electrons (bond dissociation energies) appeared to play the most significant role in delaying rancidity, while the ability to chelate metals and the distribution between oily and aqueous phases were not

correlated with inhibitory activities. The latter finding may reflect the type of matrix, fish muscle, in which the oxidative activity was studied. Caffeic acid was the most effective of this antioxidant group (similar to propyl gallate).

Potapovich and Kostyuk (2003) reported that, of a variety of flavonoids (rutin, dihydroquercetin, quercetin, epigallocatechin gallate and epicatechin gallate), the catechins were the most effective in inhibiting microsomal lipid peroxidation. All were able to chelate Fe^{2+}, Fe^{3+} and Cu^{2+} and were effective $^{\bullet}O_2^-$ scavengers to varying degrees. Authors speculate that the relative ability to scavenge $^{\bullet}O_2^-$ may be responsible for the relative antioxidative difference among these compounds.

Many of the antioxidative flavonoid compounds are naturally occurring pigments. It appears that chloroplast-located flavonoids perform a photo-protective role against O_2^- in plants. Anthocyanins are the glycosides of polyhydroxy or polymethoxy derivatives of the flavylium cation. Anthocyanins exhibit visual color because of the extreme mobility of the electrons within the molecular structure (double bonds) in response to light in the visible spectrum (approximately 400 to 700 nm). The pigments are quite water soluble and 4-OH groups are bound to the aromatic rings. The pH has a significant effect on anthocyanin pigments. These -OH groups can give up H^+ (in a basic solution) or $H^{\bullet}$ to an oxidizing lipid ($ROO^{\bullet}$) (M. Brewer, 2011).

Proanthocyanidins also contain multiple -OH groups that can donate hydrogen, quench $^{\bullet}O_2^-$ and chelate metals. Free radical scavenging ability increases as the number of phenolic -OH groups increases. Proanthocyanidins with demonstrated antioxidant activity and potential biologically therapeutic effects occur in fruits (apples and cherries), some berries (rosehips, raspberries, blackberries and strawberries), as well as in the leaves (tea), seeds (grape, sorghum, soy and cocoa bean) and bark of many plants (M. Brewer, 2011).

Functional Meat Products

The science of functional foods is the convergence of two major events in our lives-diet and health. The association between food and disease is widely recognized as the bedrock of preventive nutrition. The concept of "functional foods" is often cited as a

newly emerging field. However, this idea was first described in the ancient Vedic texts from India and in Chinese traditional medicine. The vision to develop functional foods reflects the oriental philosophy that: "Medicine and food have a common origin" (Henry, 2010).

The conviction to develop functional foods first emerged in Japan in the 1980s when faced with escalating health–care costs. The Ministry of Health and Welfare initiated a regulatory system to approve certain foods with documented health benefits. Its primary objective was to improve the health of the nation's ageing population. In 1984, the Ministry of Education, Science and Culture, an ad hoc group in Japan commenced a national project to explore the link between food and medical sciences. The term "functional food" first appeared in 1993 in the Nature news magazine under the heading "Japan explores the boundary between food and medicine" (Henry, 2010).

Functional foods may be broadly grouped into the following:

1) Conventional food containing naturally occurring bioactive substance. An example could be β–glucan in oat bran to lower blood cholesterol.

2) Foods that have been modified, by enrichment or other means, with bioactive substances. An example could be margarine that contains added phytosterol that is known to lower serum cholesterol.

3) Synthesized food ingredients, such as some specialized carbohydrates intended to have probiotic effects (Henry, 2010).

Functional foods are generally considered as those foods which are intended to be consumed as part of the normal diet and that contain biologically active components which offer the potential of enhanced health or reduced risk of disease. Examples of functional foods include foods that contain specific minerals, vitamins, fatty acids or dietary fiber, foods with added biologically active substances such as phytochemicals or other antioxidants and probiotics that have live beneficial. According to this definition, unmodified whole foods such as fruits and vegetables represent the simplest form of a functional food. For example, broccoli, carrots, or tomatoes would be considered functional foods because they are rich in such physiologically active components as sulforaphane, beta carotene and lycopene, respectively (Subirade, 2007).

The functional food concept in meat industry recently met new challenges, especially since the International Agency for Research on Cancer of the World Health Organization classified processed meat as a Group 1 carcinogen for humans in 2015. This was mainly because of the presence of N–nitroso compounds and polycyclic aromatic hydrocarbons (PAHs) in meat products. As the design of functional meat products includes two main strategies, the addition of functional ingredients and the reduction of potentially harmful components, the importance of the latter strategy have especially grown (Vasilev et al., 2017).

Numerous low fat or fat free meat products have been developed in many countries, with the United States at the head of the list. Recently, sugar–free meat products, such as roast ham and sausages, have been developed in Japan. In addition to these “free” and “low” type of products, meat products with additional physiologically functional properties have been introduced in some countries. Such functional ingredients, including vegetable proteins, fibers (e.g., oats, sugar beet, apples, peas, soy beans), antioxidants and probiotics (intestinal *Bifidobacterium* and *Lactobacillus*), have been utilized for meat products.

Dietary fibers and soy proteins have been utilized as functional ingredients in FOSHU meat products in Japan. For example, pork sausage products containing indigestible dextrin, water–soluble dietary fiber prepared from potato, are claimed to have beneficial effects on intestinal disorders. Another product is a sausage containing soy proteins. It is claimed that acceptable blood cholesterol levels can be maintained by consuming this product. In addition to the approved FOSHU products, meat products with additional functional food ingredients, such as fibers, vegetable proteins and minerals (e.g., calcium), have been developed in Japan. Soy proteins are popular vegetable proteins for their various health–enhancing activities (e.g., prevention of cardiovascular diseases, cancer and osteoporosis). A sausage with additional potato starch was developed in the United States. Such dietary fibers improve intestinal microflora as prebiotics, as described in a later section and they contribute to the reduction of fat intake. Healthier lipid formulation is also a critical approach for developing meat–based functional foods (Arihara and Ohata, 2011).

Importance of reducing fat in processed meat products

Fats and oils play important functional, sensory and nutritional roles in various food products. Fats interact with other ingredients to develop texture and mouthfeel and assist in the overall sensation of lubricity in foods (Giese, 1996). Fat present/added into meat products also plays an important role in rheological and structural properties as well as providing a unique taste profile (Jiménez–Colmenero, 2007; Rakosky, 1970). Animal fats are relatively high in saturated fatty acids compared to vegetable oils such as canola and olive oil, and animal fats contain cholesterol; both factors have been implicated in increasing plasma low density lipoprotein (Grundy and Denke, 1990). The proposed relationships between cholesterol level and low polyunsaturated/saturated fatty acids (PUFA/SFA) ratio and the rise in coronary heart diseases has resulted in focusing on high fat food products including several meat products.

Studies on fat reduction in meat products started to appear in the scientific literature in the 1970s but intensified in the early 1990s and are obviously a hot topic in the new millennium. Early work on reducing fat content in ground meat products (e.g., from 25 to 10% and below) often resulted in cooked hamburger patties that were bland and dry with a hard, rubbery or mealy texture (Berry and Leddy, 1984). However, reformulation with certain fat substitutes improved particle binding and lack of beef flavor and reduced browning reactions and shorter microbiological shelf life to a certain extent. Sausages (e.g., salami, bologna) produced with low fat (≤10%) showed reduced cook yields, soft mushy interiors, excessive purge in vacuum packages, shorter shelf life and changes in sensory qualities after cooking or reheating.

Addition of vegetal products

Vegetables are the main ingredient of a range of meat–free dishes and convenient products such as vegetable burgers, vegetable–based sausages, vegetable grills and ready meals. The attributes of vegetables include high fiber, low fat and low energy density. Particular types of vegetables can also be a good source of vitamins including vitamin C, folic acid, other B vitamins, vitamins E, vitamins K, potassium, dietary antioxidants such as carotenoids and flavonoids and a range of other potentially beneficial phytochemicals.

Protein derivatives of vegetable origin have been used in meat products for technological purposes to reduce formulation costs and they have even been used for their nutritional value (Jiménez–Colmenero, Carballo and Cofrades, 2001). The use of wheat protein as a meat alternative is a relatively recent development. Wheat protein is essentially made from gluten that has been processed and extruded to resemble the texture of meat (Sadler, 2004).

Modi et al. (2004) studied the effect of adding different decorticated legume flours to buffalo meat burgers and showed that the inclusion of roasted black gram flour led to lower thiobarbituric acid values before frying and found the burger organoleptically acceptable even after storage at –16±2°C for 4 month.

Nuts provide high levels of protein. Several studies have demonstrated an inverse association between nut consumption and the risk of cardiovascular diseases (CHD). Although nuts are high in fat, they contain a high proportion of unsaturated fats, including monounsaturated fats, which can contribute a cholesterol–lowering effect when used to replace dietary fatty acids and/or carbohydrate. Walnuts, peanuts and almonds are also a source of linolenic acid, as are mycoprotein and soya oil. Nuts also contain dietary fiber and various bioactive compounds such as plant sterols, which have cholesterol lowering properties (Halsted, 2003; Sadler, 2004).

The addition of walnuts to restructured beef steak was studied by Jiménez Colmenero et al. (2003). The results showed that the addition of walnuts affects the cooking properties, color, texture and sensory attributes, making the product softer and providing it with better water binding properties. Product morphology studies suggested that walnut interferes with the formation of protein network structures.

Addition of fiber

Epidemiological research has demonstrated a relationship between a diet containing an excess of energy dense foods rich in fats and sugar and the emergence of a range of chronic diseases, including colon cancer, obesity, cardiovascular diseases and several other disorders (Beecher, 1999) and, thus, an increase in the level of dietary fiber in the daily diet has been recommended (Johnson and Southgate, 2013). The presence of fiber in foods produces a diminution in their caloric content.

Fiber is suitable for addition to meat products and has previously been used in cooked meat products to increase the cooking yield due to its water–binding and fat–binding properties and to improve texture (Cofrades et al., 2000). Various types of fiber have been studied alone or combined with other ingredients for formulations of reduced fat meat products, largely ground and restructured products and meat emulsions (Grigelmo–Miguel, Abadı´as–Serós and Martı´n–Belloso, 1999).

In studies by Yılmaz (2004), rye bran was used as a fat substitute in the production of meatballs. Rye consumption has been reported to inhibit breast and colon tumor growth in animal models, to lower glucose response in diabetics and to lower the risk of death from coronary heart disease. The addition of rye bran to meatballs at the levels assayed (5 to 20%) improved their nutritional value and health benefits. The total trans fatty acid content was lower and the ratio of total unsaturated fatty acids to total saturated fatty acids was higher in the samples with added rye bran. The authors concluded that this type of fiber can be used as dietary fiber source.

Another source of fiber is oat. Many of the characteristics of oat fiber such as its water–absorption capacity could potentially benefit products such as fat–free frankfurters and low–fat bologna. Oat products have also achieved a very positive consumer image because of the health benefits that have been associated with their consumption. Oat was added by Steenblock et al. (2001) to determine the effects on the quality characteristics of light bologna and fat–free frankfurters. Different types of oat fiber were used, high absorption (HA) or bleached oat (BL) fiber at levels up to 3%. The results indicated that the addition of both types of oat fiber produced greater yields and a lighter red color. Purge was reduced with oat fiber at 3%. Product hardness increased for bologna. It has been reported that oat bran and oat fiber provide the flavor, texture and mouthfeel of fat in ground beef and pork sausages (Garcı´a et al., 2002).

The components of dietary fiber include fructooligosaccharides (FOS), a generic name for all nondigestible oligosaccharides composed mainly of fructose. The effect of a short–chain FOS on cooked sausages was studied by Cáceres et al. (2004). The addition did not affect the pH, a_w or weight losses because the presence of soluble dietary fiber (SDF) leads to a compact gel structure and therefore prevents proteins from retaining the

water. The energy values decreased from 279 kcal/100 g in the conventional control to 187 kcal/100 g in the reduced–fat sausages with 12% added fiber at 12% SDF. The hardness of the samples with SDF was lower and the overall acceptability in the sensory analysis was higher in samples with 12% SDF.

Another SDF is inulin, which can be used as a fat substitute mainly in nonmeat foods (cakes, chocolates, dairy products, spreads) because of its contributions to better mouthfeel, enhanced flavor and low–caloric value (1.0 kcal/g). (Mendoza et al., 2001) prepared low–fat, dry–fermented sausages with a fat content close to 50 and 25% of the original amount and supplemented with 7.5 and 12.5% of inulin. The results indicate that inulin impacts a softer texture and a tenderness, springiness and adhesiveness very similar to that of conventional sausages. A low calorie product (30% of the original) can be obtained with approximately 10% inulin.

Epidemiological studies have shown that the consumption of fruits and vegetables imparts health benefits, for example, reduced risk of coronary heart disease, stroke and certain types of cancer. Apart from the dietary fiber, fruits and vegetables contain health benefits that are mainly attributed to organic micronutrients such as carotenoids, polyphenolics, tocopherols, vitamin C and others (Schieber, Stintzing and Carle, 2001).

Inner pea fiber was identified as an ingredient capable of retaining high fat and water in ground beef. Inner pea fiber is manufactured from the inner cell walls of yellow field peas and contains approximately 48% fiber, 44% starch and 7% protein. This fiber may improve the sensory properties of lower fat ground beef by retaining substantial amounts of both the moisture and fat that are normally lost during cooking. This source was added in a dry form by Anderson and Berry (2000) to lower fat beef patties (10 and 14%), in which it improved tenderness and cooking yield without having negative effects on juiciness and flavor.

Another important source of fiber is fruits, which can also be obtained as by–products of plant food processing. Citrus byproducts (lemon albedo and orange fiber powder) have been added, at different concentrations, to cooked and dry–cured sausages with excellent results.

Lemon albedo was added at different concentration (2.5 to 10%) to cooked sausages (Fernández-Ginés et al., 2004) and dry-cured sausages (Aleson-Carbonell et al., 2005). The addition of lemon albedo to both sausages had healthy effects due to the presence of active biocompounds, which induced a decrease in residual nitrite levels. Sausages with 2.5 to 7.5% lemon albedo added had sensory properties similar to conventional sausages.

Orange fiber powder was added at different concentrations (0.5 to 2%) to cooked sausages (bolognas). The results showed that the addition improved the nutritional value, decreased the residual nitrite level and delayed the oxidation process as determined by TBA values and the red color. Citrus fiber at all concentrations made the products harder and less springy and chewy. All the samples had a similarly good score in the sensory analysis, except the sample with 2% citrus fiber (Fernández-Ginés et al., 2003).

García et al. (2002) studied the effect of adding cereal and fruit fibers on the sensory properties of reduced-fat, dry-fermented sausages. The cereal (wheat and oat) and fruit (peach, apple and orange) dietary fibers were added at 1.5 and 3% concentrations. The addition of dietary fiber from cereals and fruits at 1.5% resulted in sausages with a final fiber content, after ripening, of about 2%, which represents an improvement in their nutritional properties and provides an acceptable sensory profile. Higher amounts of fiber (3%) increased the hardness, resulting in products with a lower sensory quality. The best results in this study were obtained with sausages containing 10% pork backfat and 1.5% fruit fiber. The orange fiber provides the best results with sensory properties similar to those of conventional sausage.

Eggplant

Eggplant (*Solanum melongena* L.), also known as Aubergine, Brinjal or Guinea squash is one of the non-tuberous species of the night shade family Solananceae. The varieties of *Solanum melongena* L. show a wide range of fruit shapes and colors, ranging from oval or egg shaped to long club shaped; and from white, yellow, green through degrees of purple pigmentation to almost black. It is a native of the subtropical areas of south eastern Asia and was introduced into Europe by early Arab traders. Eggplant is

commonly used around the world to make the all-vegetable dish Ratatouille in France, Curry in India, Babaganoush spread or dip in the Middle East, Moussaka in Greece, or Eggplant Parmesan in Italy. In addition, it is commonly added to Asian stir-fried dishes or grilled on the BBQ in North America and Australia, in addition to many other culinary uses.

Nutritional value of eggplant

Eggplant is known as one of the ten sources of the world's healthiest food (Caguiat and Hautea, 2014). Eggplants contains numerous nutrients which are all needed in the body predominantly for growth, repair of worn out tissues and then for protection. They are made up of a host of vitamins and minerals, dietary fiber, proteins, antioxidants, as well as phytochemicals that possess antioxidant activity. The nutritional information of raw eggplant declared by the supplier is listed in Table 3. Moreover, the fruit contains important phytonutrients such as phenolic and flavonoid compounds which have high antioxidant capacities. Phenolic compounds and antioxidant activity are found in most parts of the eggplant, including peel, leaf, calyx, pulp and stem (Chumyam et al., 2013). The antioxidant capacity and total phenolic content of purple skin eggplants have been reported to be higher than those of green and white skin cultivars due to purple eggplants have anthocyanin antioxidant compounds, which can be seen in eggplant's rich purple colors (Azuma et al., 2008). In a study conducted by Jung et al. (2011) the purple eggplant peel have high anthocyanins content (138.05 mg %) followed by calyx (135.94 mg %), stem (110.38 mg %), leaf (97.29 mg %) and pulp (2.29 mg %) extracts.

Table 3 Nutritive composition of 100g edible portion of fresh eggplant

Nutrients	Value
Energy	25.00 Kcal
Moisture	92.30 g
Carbohydrates	5.88 g
Protein	0.98 g
Total Fat	0.18 g
Dietary Fiber	3.00 g
Vitamins	
Folates	22 µg
Niacin	0.649 mg
Riboflavin	0.037 mg
Thiamin	0.039 mg
Vitamin A	23 IU
Vitamin C	2.2 mg
Vitamin E	0.30 mg
Vitamin K	3.5 µg
Electrolytes	
Sodium	2 mg
Potassium	229 mg
Minerals	
Calcium	9 mg
Copper	0.082 mg
Iron	0.23 mg
Magnesium	14 mg
Phosphorus	24 mg
Zinc	0.16 mg

Source: USDA: United States Department of Agriculture (2017)

Benefits of anthocyanin

Anthocyanins (from the Greek anthos = flower and kyano = blue) are phenolic compounds classified inside of the flavonoids group and they are considered the largest and most important group of water soluble pigments in nature (Miguel, 2011). Based on their chemical characteristics, flavonoids are divided into different subclasses: flavonols, flavanols, anthocyanidins, flavanones, flavones and isoflavones (Ramos, Herrera and Moya–León, 2014). Anthocyanins are considered the most important group of flavonoids in plants having more than 600 compounds identified in nature. Nevertheless, only six anthocyanidins (cyanidin, delphinidin, malvidin, pelargonidin, peonidin and petunidin) are widely distributed in nature (Ramos, Herrera and Christerson, 2016; Moya–León, 2014). The anthocyanidins are the basic structures of the anthocyanins. Anthocyanidins consist of an aromatic ring (A ring) bonded to a heterocyclic ring (C ring) that contains oxygen, which is also bonded by a carbon–carbon bond to a third aromatic ring (B ring) (Castañeda–Ovando et al., 2009). Their basic skeletons can therefore be described as C_6–C_3–C_6, a total of 15 carbons (Figure 3).

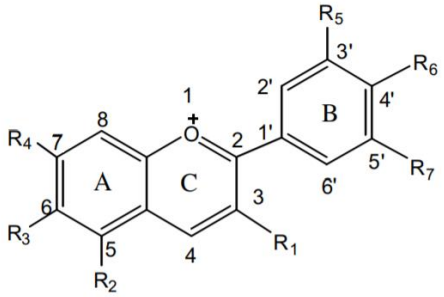

Figure 3 General structure of anthocyanidin

Source: Castañeda–Ovando et al. (2009)

Anthocyanins are natural pigments that provide intense colors of blue, purple and red pigmented flowers, fruits and vegetables. Edible anthocyanin sources in nature include colored fruits such as berries, cherries, grapes and plums as well as many dark–colored vegetables such as black currant, red onion, red radish, black bean, purple eggplant,

purple corn and purple sweet potato (He and Giusti, 2010). Anthocyanin rich foods are becoming more popular in the role of antioxidants in human health has triggered intense research in the field of agronomic and food sciences (J. Guerrero et al., 2010). Several studies have demonstrated that anthocyanin extracts have the free radical scavenging and antioxidant capacities to intervene with human therapeutic targets. Epidemiologic studies suggest that the consumption of anthocyanins lowers the risk of cancer, cardiovascular disease, arthritis and diabetes, due to their antioxidant anti-inflammatory properties (Miguel, 2011). Anthocyanins present in some food and beverages have shown to play an important role in the prevention of diverse diseases.

Antioxidant activity of anthocyanin

Natural antioxidants are produced in living cells to maintain a delicate oxidation-reduction balance in the process of nutrient metabolism and immune function. Upon oxidative stress, antioxidants will react with radical and non-radical species to initiate defense mechanisms for the protection of both intracellular and extracellular components. The plant kingdom is the most abundant source of antioxidants, which are richly present in spices (seeds), herbs and essential oils used in meat products for organoleptic purposes (Jiang and Xiong, 2016). In foods, oxidation can be one of the main causes of alterations leading to rancidity, deterioration and loss of nutritional, commercial and organoleptic qualities (colour, taste, smell and texture) (Martín et al., 2017). Antioxidants are added to different meat products to prevent lipid oxidation, retard development of off-flavors and improve color stability. Moreover, plant-derived antioxidants provide meat processors with the flexibility to develop novel products with enhanced nutritional value and health benefits, an improved shelf-life and an attractive overall quality profile (Jiang and Xiong, 2016). The antioxidant ability of anthocyanins depends on the basic structural orientation of the compound because the ring orientation will determine the ease by which a hydrogen atom from a hydroxyl group can be donated to a free radical as well as the capacity of the anthocyanin to support an unpaired electron (Miguel, 2011).

Starch

Starch (Figure 4) is a pure carbohydrate polymer and the most common sources are potato, wheat, rice, tapioca (cavassa) and corn (maize). It is also the form in which energy in plants is stored, whereas glycogen is the source of energy for humans and animals. Starch is a polysaccharide and consists of anhydrous α–D–glucose units containing the elements hydrogen, oxygen and carbon. A starch granule is crystalline and the position of the starch molecules forms radially directed crystals. If polarized light penetrates through a starch granule, the granule is divided into wedge–shaped sections by dark lines, which is known as birefringence. A granule of starch has an organized structure and the amylose and amylopectin that it contains are oriented from the interior outwards (Feiner, 2006).

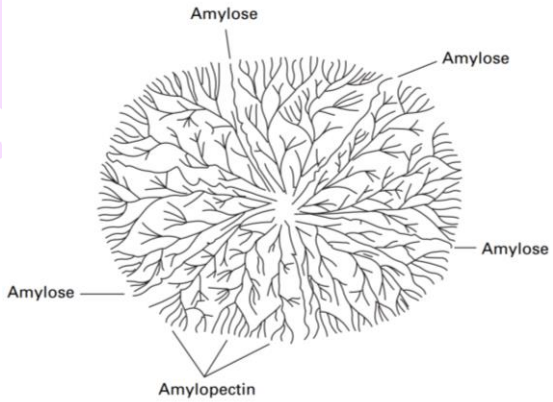

Figure 4 A starch molecule

Source: Feiner (2006)

Starch is non–sweet and contains a small amount of protein as a very thin layer of protein covering each starch molecule. The protein level in starch varies between 0.1% and 0.7% and moisture is present at a level of 12 to 18%.

The two major components of starch are amylose (Figure 5) and amylopectin. Different types of starch have different ratios of amylose to amylopectin. Amylose consists

of straight (or linear) chains of 200 to 15000 anhydrous glucose units, which are tightly bound together via hydrogen bonding by α–D–1,4 glycosidic bonds.

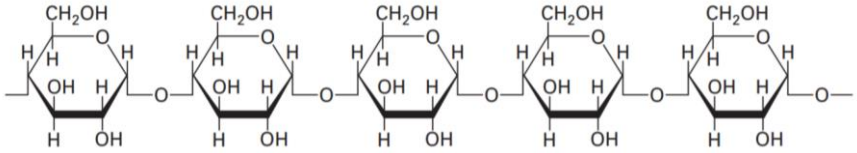

Figure 5 Amylose

Source: Feiner (2006)

Amylose is primarily responsible for the firmness or gel strength of a starch gel as the linear chains of glucose units can align themselves in a parallel way and close to each other. Such an alignment restricts the access of water, enzyme activity is reduced. The tight alignment is also the reason why starch high in amylose requires higher temperatures to gelatinize and why enzyme activity during the digestion is slowed; high–amylose starch is known for their low glycaemic index (GI).

Amylose is also very unstable in aqueous solutions and intermolecular interaction and association with other amylose molecules can lead to an increase in viscosity, retrogradation and even precipitation of amylose particles. Retrogradation in amylose gels is a process whereby the linear amylose molecules align themselves closely next to each other upon cooling and some water, formerly bound within the gel, is released. When a starch slurry in a cooked meat product is still hot, the amylose particles move freely within the hot slurry and the water is immobilized. If the hot starch slurry in the meat product is cooled very slowly, retrogradation takes place; the amylose particles align themselves very closely next to each other owing to their linear structure, squeezing out water. Cooling too quickly, however, also leads to retrogradation as the amylose particles have insufficient time to set up such an organized three–dimensional gel structure. Because of this, a meat product containing starch should be cooled quickly enough to avoid retrogradation caused

by slow cooling but should not be placed, for example, into a freezer during the cooling period, as this would also cause retrogradation to take place.

Storage of meat products containing high–amylose starch, at low temperature from around –1 to 0℃ for a prolonged time also favours retrogradation. The level of retrogradation depends on the type of starch and increases in the sequence tapioca > potato > maize > wheat, with wheat starch demonstrating the greatest tendency towards retrogradation. Syneresis and purge (weeping) are seen as a result of retrogradation and this is very common in sliced and vacuum–packed meat products.

The second major component of starch, amylopectin (Figure 6), also consists of chains of glucose but, unlike amylose, the molecule is highly branched. Short side chains of about 30 – 35 glucose units are bound to the main amylose – glucose chain after every 20 – 30 glucose units, resulting in a highly branched structure. The branches open up the molecule and therefore the glucose units are not packed together as tightly as amylose. Amylopectin can have up to 1.5×10^6 glucose units per molecule.

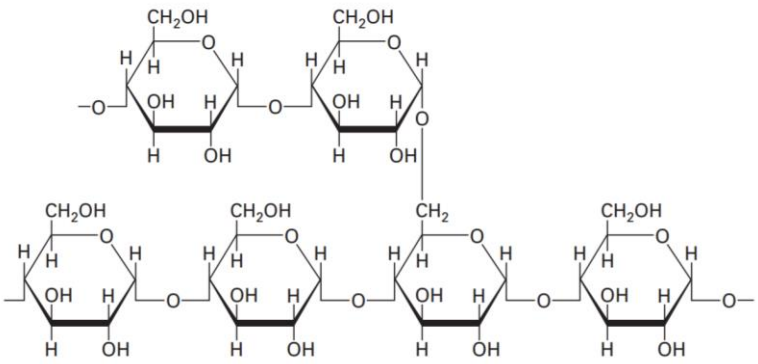

Figure 6 Amylopectin

Source: Feiner (2006)

Amylopectin is responsible for the elasticity and viscosity of a starch gel and viscosity is primarily a function of molecular weight and particle size. Given that the branched amylopectin is significantly larger than amylose, it builds viscosity better then amylose. Starches high in

amylopectin are easier to cook and generally gelatinize at lower temperature than starch high in amylose. The branching within the molecule also means that amylopectin has less tendency to retrograde.

High-amylopectin starch is easy to digest and have a high GI. The GI demonstrates the immediate impact of a carbohydrate food on blood glucose levels (Figure 7). Sugars with a high GI break down quickly during digestion and raise the level of blood sugar quickly, whereas low-GI sugars are released slowly into the bloodstream, raise the blood sugar level gradually and are converted into fat more slowly. Examples of high-GI foods are potatoes and white bread; an example of a low-GI food is rye bread. Sugars with a high GI value often contribute to poor health.

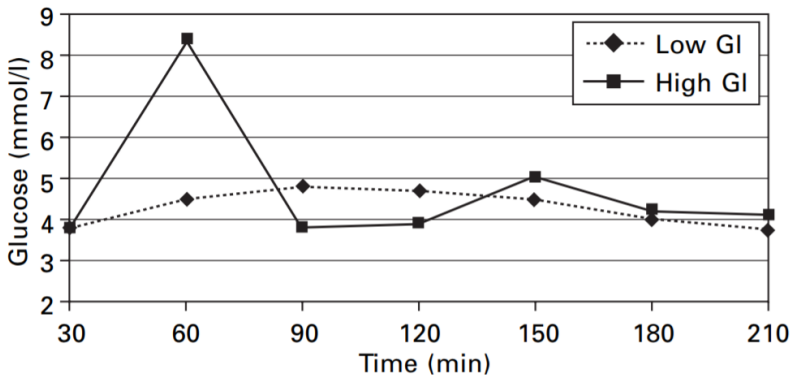

Figure 7 The effect of the GI on blood glucose levels

Source: Feiner (2006)

Starch, which contains 97% or more amylopectin and therefore little or no amylose, is collectively known as waxy starch. This type of starch results in clear and transparent gel and does not retrograde primarily because of the high percentage of branched molecules, but also because of the absence of amylose. Waxy starches generally demonstrate good freeze-thaw stability and are also used for heat-freeze processes. Other types of waxy starch contain 99% amylopectin.

Table 4 shows the different characteristics of starch commonly used. In general, root or tuber starch swells more rapidly and in a narrower temperature range than cereal starch. Rice starch is the most neutral tasting starch whilst modified tapioca and potato starch demonstrate good freeze thaw stability. Both also contribute to a smooth mouth feel in a cooked meat product and are frequently utilized in low fat products as the smoothness from the starch compensates for the lack of smoothness from fat. Modified tapioca and potato starch also gelatinize at lower temperature, which results in an increased cooking yield in meat products compared with native potato and tapioca starch. Potato starch has low lipid content, therefore showing little flavor interference with the natural flavor of meat and also has a strong synergistic effect with soy protein. Native potato starch and tapioca starch, however, are generally very hard to inject into meat products as they show limited dispersibility in cold water and potato starch also forms sediment quickly within brine. Modified potato starch produces a firm gel texture and is excellent for use in injected and tumbled meats as well as in marinade for meat. Furthermore, potato starch demonstrates a high peak viscosity and is commonly used in applications where adhesive qualities (batter and marinades) are required.

Table 4 Characteristics of various types of starch

Type of starch	Amylose (%)	Amylopectin (%)	Size (μm)	Swelling capacity
Potato	21	78	25 – 80	700
Corn/maize	26	65 – 70	5 – 20	24
Rice	20	78	3 – 8	19
Tapioca	15 – 18	80 – 85	5 – 25	75
Wheat	27	75	25	21
Waxy maize	2	95 – 98	5 – 25	65

Source: Feiner (2006)

Native pea starch has characteristics similar to cross-linked modified starches and is also quite robust towards high-temperature treatment, shearing forces and low pH values. Corn starch generally forms a weak and brittle gel.

Granule size does not have a significant impact on the performance of starch. It is predominantly how fast a starch gelatinizes as well as the final gelatinizing temperature which determines functionality to a large degree. In general, the swelling of a starch molecule under the impact of moist heat takes place more rapidly in larger molecules, such as tapioca. In larger starch molecules in the presence of heat, the linear structure of amylose within starch lines up readily and there is an increased level of hydrogen bonding. As a result, more energy is required to break the bonds within high–amylose starch and gelatinize the material.

Starch also contains phosphorus in various forms and the nature of the phosphorus affects the performance of starch. In most cereal starch, phosphorus is presented as lysophospholipids, which will form a complex with the amylose, therefore reducing the WBC, which results in an opaque paste. The viscosity of starch in solution is expressed in Brabender units. It is also of interest that heating starch quickly compared with slowly, but reaching the same final temperature, results in more viscous slurry.

Modification of starch

Native or unmodified starch is obtained from the original form of the starch–bearing material. Native starch exhibits generally limited resistance towards low pH values in food, the impact of heat during processing and poor performance regarding freeze–thaw stability. Therefore, modification of starch is common practice in order to improve the behavior of starch towards such processing parameters. Modified starch is ordinary or native starch altered physically or chemically to modify its functional properties such as thickening or gelling (Feiner, 2006).

Physically modified starch undergoes various processes such as drum drying, extrusion and spray drying in order to obtain pregelatinized, agglomerated or cold–water–swelling starch. Within those physical processes, no chemicals are applied and such modified starch maintain their “clean image”. Pregelatinized starch is cold swelling and does not require much heat in order to thicken or form a gel or paste. They are commonly obtained via spray drying, drum drying or extrusion from modified or native starch. Pregelatinized starch develops viscosity in cold and warm water and have been gelatinized already before being dried again to obtain the material in a powdered form.

Pregelatinized starch is also known as precooked, pregelled, instant or cold-water-swelling starch.

Chemically modified starch is treated with chemicals and commonly some hydroxyl groups within the molecule are replaced with either ester or ether groups. Modification takes place primarily in the form of cross-linking as well as substitution and larger molecules are obtained. As a result, those modified materials are more robust towards the impact of processing parameters such as low pH values, high temperatures and freeze-thaw cycles. Crosslinking with materials such as phosphorus oxychloride enhances resilience towards acidity as well as high processing temperatures and is a process in which two hydroxyl groups of neighbouring starch molecules are chemically linked together. Other ways of chemical modification are substitution or oxidizing.

Substitution within the starch molecule with acetyl or hydroxypropyl increases freeze–thaw stability and reduces also the level of retrogradation. Highly substituted starches result in water-soluble materials and some starch is dual modified, cross-linked and substituted. Oxidation of starch enhances crispiness in certain foods such as cereals and oxidized starch are commonly not applied in meat products.

Cellulose is a glucose polymer and generally the main component of cell walls. The enzyme amylase can break down starch into glucose units but cannot break down cellulose and only the enzyme cellulase can break down cellulose into its basic components. Carboxymethyl cellulose is normally insoluble in water but made water-soluble through modification. This is achieved by the introduction of active methyl, hydroxyl or propyl groups on to the OH group of the cellulose (Feiner, 2006).

Gelatinizing of starch

Once starch in water or in a meat product is heated under moist conditions, water penetrates into the starch granule until fully hydrated. Root and tuber starch swell more rapidly in a narrower range of temperatures than cereal starch. Upon full hydration, the hydrogen bonds between amylose and amylopectin maintain the integrity of the granule and the granule begins to swell from the inside out upon the continued impact of heat. During swelling and hydration, the size of the starch molecule increases several times. Birefringence is lost, the solution becomes clearer, consistency increases dramatically

and a peak is reached. The gelatinization end point is reached when 96 to 98% of the granules have lost their birefringence. The optimal temperature for complete gelatinizing varies between the different types of starch but is generally higher within starch exhibiting a higher content of amylose, given that the amylose molecules are of linear structure and tightly aligned next to each other. Upon subsequent cooling, a paste or gel is obtained. The gelatinization point of potato starch is between 61 and 63°C, tapioca between 65 and 66°C, corn starch between 67 and 69°C, rice starch between 72 and 74°C, pea starch between 72 and 76°C and wheat starch by 75 and 77°C (Feiner, 2006).

Freeze–thaw stability of starch

Starch exhibiting good freeze–thaw stability should contain a high level of amylopectin and starch which has been acetylated, modified with phosphorus oxide (phosphorus oxide stabilized) or cross-linked performs well. Some highly freeze–thaw-stable starch is modified with phosphorus oxide as well as heavily cross-linked. Waxy starch is commonly applied in sauces and soups, which are stored frozen. Meat products, containing starch and being stored frozen, should be produced by the help of waxy starch as well in order to avoid, or reduce, syneresis during thawing. Despite that, some native starch such as waxy rice starch demonstrates better freeze–thaw stability than high-amylopectin and modified starch, which cannot be scientifically explained yet. In particular, modified tapioca and potato starch demonstrate excellent freeze–thaw stability. Most native starch such as wheat and potato starch demonstrates very poor freeze–thaw stability and a mixture of 50% native starch and 50% (or more) of a modified starch, high in amylopectin, results in a greatly improved behavior towards freezing and thawing (Feiner, 2006).

CHAPTER III

RESEARCH METHODOLOGY

Materials

Ground beef and pork fat were purchased from a butcher shop and divided into 12 batches. Purple eggplants (Japanese eggplants) were bought from Wiang Pah Pao, Chiang Rai.

Preparation of purple eggplant flour

Fresh purple eggplants were washed thoroughly under running tab water to remove all the soil and unwanted dirt. The purple eggplants together with their peels were sliced into 8 mm. thickness. After that, sliced purple eggplants dried in air dryer at 70°C for 4.5 h (air speed of 2.5 ms^{1}) (Zaro et al., 2015). Next, dry purple eggplants were ground using grinder and sieved through 500 µm mesh sieve (Uthumporn et al., 2015). The purple eggplant flour was vacuum sealed and kept in aluminum foil bag. The flour was stored in refrigerator at 4°C prior to use.

Beef patty preparation

Beef patty was produced by mixing 75% lean beef meat with 1% salt, 1.2% pepper and 3% seasoning following formula shown in table 5. This research consisted of 4 treatments group as follow: T1 were control group (contained 20% fat content basal beef patties), T2: basal beef patties with 2.5% PEF, T3: basal beef patties with 5% PEF and T4: basal beef patties with 7.5% PEF while an equivalent amount in each treatment was reduced from fat. The formulas of beef patties were shown in Table 5. The beef patty from each batch was kneaded for 10 min to obtain homogeneous dough. This mixture was shaped by using hamburger patty forming press (8.5 cm internal diameter) to obtain patties of approximately 80 g and 1.5 cm thickness. Finally, the patties were placed in plastic

containers with covers and held under frozen condition (–18°C) until analysis in designated times.

Table 5 Formulation of beef patties (%)

Treatments	Lean beef meat	Fat	Purple eggplant flour	Salt	Pepper	Seasoning
Control	75	20	0	1	1	3
1	75	17.5	2.5	1	1	3
2	75	15	5	1	1	3
3	75	12.5	7.5	1	1	3

Note: Seasoning used in recipe is soy sauce and seasoning powder

Nutritional value

Nutritional value analysis

The nutritional values of purple eggplant flour and raw beef patties were determined according to the AOAC methods. Moisture content was determined by hot air oven at 105°C until the weight becomes constant. Total crude protein was determined by Kjeldahl analysis (AOAC, 1995). Ether extract (EE) was evaluated by using dichloromethane in a Soxtec System (AOAC, 1995). Crude ash content of purple eggplant flour and raw beef patties were determined by incineration in a muffle furnace at 550 °C.

Dietary fiber

Total dietary fiber (TDF), soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) of purple eggplant flour were measured by using the Megazyme total dietary fiber analysis kit (Megazyme International Ireland Ltd., Wicklow, Ireland).

Product qualities

Water Holding Capacity (WHC)

1. Thawing loss

The thawing loss of beef patties was determined from the known weight of beef patties before and after thawing and expressed as:

$$\text{Thawing loss (\%)} = \frac{(\text{weight of raw beef patty} - \text{weight of thawed beef patty}) \times 100}{\text{weight of raw beef patty}}$$

2. Drip loss

Drip loss is the manifestation of the leakage of myofibers and loss of water and proteins during the transition of muscle to meat without mechanical force other than gravity. This method was assessed as the proportionate weight loss of a part of beef patties (g) that suspended in a plastic bag for 24 h at 4°C. Drip loss was determined by weighting the sample before and after suspending and calculated in the difference between initial and final weight and expressed in percentage.

$$\text{Drip loss (\%)} = \frac{(\text{initial weight of raw beef patty} - \text{final weight of raw beef patty}) \times 100}{\text{initial weight of raw beef patty}}$$

3. Cooking loss

Samples were grilled on a pre-heated Teflon coated pan for 5 min each side (to give an internal temperature of 72±2°C) (Yıldız-Turp and Serdaroglu, 2010) and then 10 min of cooling. The beef patties were weighed before and after cooking to determine cooking losses.

$$\text{Cooking loss (\%)} = \frac{(\text{weight of raw beef patty} - \text{weight of cooked beef patty}) \times 100}{\text{weight of raw beef patty}}$$

4. Moisture retention

The moisture retention in beef patties was determined by measuring the moisture of beef patties before and after cooking (to give an internal temperature of 72± 2°C), by using the following equation:

$$\text{Moisture retention (\%)} = \frac{\text{moisture of raw beef patty} \times 100}{\text{moisture of cooked beef patty}}$$

Cooking characteristics

1. Cooking yield

Cooking yield of beef patties was determined by measuring the weight of patties for each treatment/batch and calculating weight differences for patties before and after cooking, as follows:

$$\text{Cooking yield (\%)} = \frac{\text{weight of cooked beef patty} \times 100}{\text{weight of raw beef patty}}$$

2. Fat retention

The fat retention value represents the amount of fat retained in the product after cooking. Beef patties were grilled on a Teflon coated pan until the internal temperature reach to 72±2°C. Fat retention was calculated according to Serdaroğlu et al. (2018) by using the equation as follows:

$$\text{Fat retention (\%)} = \frac{(\text{weight of cooked beef patty} \times \%\text{fat in cooked beef patty}) \times 100}{(\text{weight of raw beef patty} \times \%\text{fat in raw beef patty})}$$

3. Diameter reduction

The diameter of each beef patty was measured before and after grilling with a digital caliper. Thereafter, beef patties (8.5 cm internal diameter) were grilled on a Teflon coated pan until the internal temperature reach to 72±2°C. Change in the beef patty diameter was determined using the following equation (Soltanizadeh and Ghiasi-Esfahani, 2015):

Reduction in beef patty diameter (%)

$$= \frac{(\text{raw beef patty diameter} - \text{cooked beef patty diameter}) \times 100}{\text{raw beef patty diameter}}$$

4. Thickness reduction

$$\text{Thickness reduction (\%)} = \frac{(\text{raw beef patty thickness} - \text{cooked beef patty thickness}) \times 100}{\text{raw beef patty thickness}}$$

Texture analysis

All mechanical properties were measured using the Texture analyzer equipped with cylindrical probe for compression and blade for cutting. Texture properties were evaluated in raw and grilled samples. Raw burgers 5.08 cm in diameter and 1 cm in thickness were compressed at the depth of 4 mm at the speed of 100 mm/min in a one–cycle compression test (Moghtadaei, Soltanizadeh and Goli, 2018). The force corresponding to the maximum compression was reported as the maximum force. At least 3 measurements were taken for each test. The shear force of the cooked beef patties was estimated with a blade attached to the texture analyzer. Cooking method was described above.

Sensory evaluations

Sensory evaluations were carried out by an experience twenty member trained panel. Twenty graduate students including 10 men and 10 women from University of Phayao were scored the beef patties samples. The sample was cooked by grilled on Teflon coated pan until core temperature reached to 72±2°C. The twenty member trained panelists rated samples according to the procedures outlined by American Meat Science Association (1995). Beef patties were evaluated for tenderness, juiciness, appearance acceptability, color liking, odor intensity, acceptance of texture, acceptance of taste, overall acceptability and off–flavor intensity amount using nine–point scale (9= like extremely, extremely tender, juicy and extremely high off–flavor; 1= dislike extremely, extremely tough, dry and no off–flavor).

Storage stability

Color measurement

Color was measured at the surface of raw beef patties. Color measurements were carried out using a chroma meter (Konica Minolta, CR-400, Japan). The samples were homogenized and filled into Petri dishes before measuring. Six time per sample were taken and the mean value was calculated for each of the three replications. Lightness (L*), redness (a*) and yellowness (b*) values were also determined using the procedure suggest by Gök et al. (2011). The instrumental color was measured at 0, 1, 3, 5 and 7 days of refrigerated storage.

Malondialdehyde (MDA) determination

1. Extraction of Thiobarbituric Acid Reactive Substances (TBARS) in raw beef patties samples.

Two grams of raw beef patties were homogenized in 8 ml of trichloroacetic acid (TCA) (5 ml/100 ml) and 5 ml of BHT (0.8 ml/100 ml) (butylhydroxytoluene) in hexane for 1 min. After that, the samples were centrifuged for 10 min at 1.028 g. Later, the supernatant was removed and the volume complete until 10 ml with the TCA solution. An aliquot of 2.5 ml was taken from each sample by triplicate and added 1.5 ml of thiobarbituric solution. All samples were put in a water bath at 70°C for 30 min. and cooled in a water bath until room temperature (22±2°C) (Garrido et al., 2011).

2. Determination of MDA by High Performance Liquid Chromatography (HPLC)

The HPLC determination of MDA, the procedure was described by Papastergiadis et al. (2012) was followed, with slight modifications. A total of 1 mL of extract and 3 mL of TBA reagent (40 mM dissolved in 2 M acetate buffer at pH 2.0) were mixed in a test tube and heated in a boiling water bath for 35 min.

Separation and HPLC analysis of MDA as well MDA-DNPH adduct were performed using high-performance liquid chromatography (HPLC). The HPLC system Dionex UltiMate 3000 RS (Thermo Fisher Scientific, Braunschweig, Germany) consists of a quaternary pump, degasser, automated injector, column oven and diode array detector (DAD). The DAD detector was set to collect signals within the spectral range of 190 to

800 nm. Chromatographic separation was achieved on the chromatographic column Polaris C18–A (particle size, 5 µm; column size 250 mm × 4.6 mm; Varian, Santa Clara, CA, USA). Samples were isocratically eluted with a mixture of 0.2% (v/v) glacial acetic acid in deionized water and acetonitrile (61:39, v/v) at a flow rate of 1 mL/min at 25 °C. The injection volume is 20 µL and the DAD detector was set at 307 nm. Analyses were performed with Chromeleon Chromatography Data System, Version 7.2 (Thermo Fisher Scientific, Braunschweig, Germany) for collecting and processing data. Each analysis was performed in three replicates. All solvents were filtered through a Whatman filter paper no. 4 before use. A calibration curve was prepared by mixing a 500 µL volume of each of the above mentioned concentrations of standard of MDA and 50 µL of DNPH were added into a vial and the resulting solution will be incubated at room temperature for 30 min in the dark. The clear solution was transferred into a vial and then 20 µL of the resulting solution were injected onto to a column for chromatographic analysis. Triplicate 20 µL injections were made for each standard solution to see the reproducibility of the detector response at each concentration level. The peak area of MDA–DNPH was plotted against the concentration to obtain the calibration graph. The MDA–DNPH peak was identified by the elution profile of the authentic standard Peak identification in meat samples was performed by comparison of the retention time with the standard (Reitznerová et al., 2017). All samples were determined MDA by RP–HPLC at 0, 1, 3, 5 and 7 days under refrigerated storage.

Statistical analysis

Data of color measurement and MDA determination was arranged in a factorial in completely randomized design (4 × 5 factorial in CRD) with three replications. Two factors are flour level of purple eggplant (0, 2.5, 5 and 7.5%) and five stages of storage stability (0, 1, 3, 5 and 7 days). Other parameters were analyzed as a completely randomized design. All data were analyzed by ANOVA with GLM procedures of SAS program (1996). The least squares mean (LSM) was compared for significant difference using Duncan's New Multiple Range Test ($p<0.05$).

CHAPTER IV

RESULTS

Chemical compositions

1. Chemical compositions of purple eggplant flour (PEF)

The chemical compositions and dietary fiber of purple eggplant flour were shown in Table 6. PEF had moisture content about 10.79±0.14 and 10.48±0.4% of protein. PEF contained a low level of fat (1.87±0.05%). For total dietary fiber content (TDF), PEF contained 37.86±0.63% of total dietary fiber, which included 33.83±0.29% of insoluble dietary fiber (IDF) and 4.03±0.57% soluble dietary fiber (SDF) in TDF of PEF.

Table 6 Chemical compositions of purple eggplant flour

Item	Amounts (%)
Moisture	10.79±0.14
Protein	10.48±0.42
Fat	1.87±0.05
Total Dietary Fiber (TDF)	37.86±0.63
Insoluble Dietary Fiber (IDF)	33.83±0.29
Soluble Dietary Fiber (SDF)	4.03±0.57

2. Chemical compositions of beef patties formulated with different levels of purple eggplant flour

The chemical compositions of raw low fat beef patties formulated with different levels of PEF were shown in Table 7 and expressed as % of DM. Composition of meat products was influenced by different level of PEF. The chemical compositions of raw low fat beef patties were significantly different ($P<0.05$) among treatments except carbohydrate. Conventional patties (control groups) as expected showed the highest fat content (23.35± 0.42%). The moisture content of patty samples increased ($P<0.05$) with increasing level of

PEF. The lowest moisture content was determined for control beef patties as 57.75± 0.22%. Moisture content in beef patties with added PEF (2.5, 5 and 7% PEF) were 59.77± 0.52, 62.13±0.66 and 63.40±0.11%, respectively. On the other hand, the protein content decreased (P<0.05) with increasing amounts of PEF. The protein content of control beef patties was 15.80±0.18% and ranged from 14.59±0.11 to 15.27±0.17% for beef patties with added PEF. This could be attributable to the increase in moisture content. The fat values of patties samples decreased (P<0.05) when PEF was added since 2.5%. The fat content of control groups (23.35±0.42%) was significantly higher than beef patties formulated with PEF (20.48±0.36, 17.68±0.26 and 16.18±0.66% of fat content, respectively). Beef patties with PEF added at any concentration showed higher ash content (P<0.05) than control (2.29±0.52, 3.39±0.30 and 3.22±0.32% VS 1.01±0.16%, respectively). The carbohydrate content of control was 2.10±0.17% and beef patties contained PEF (2.5, 5 and 7% PEF) were 2.19±0.46, 2.07±0.03 and 2.61±0.43%, respectively. Carbohydrate content of all samples had no significant differences (P>0.05). The addition of PEF significantly increased the dietary fiber of beef patties (0.90±0.71, 2.22±0.29 and 4.23±1.22%, respectively), while the control group was not detected.

Table 7 Chemical composition of raw low fat beef patties contain different percentage of purple eggplant flour (% of dry matter)

Treatment	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)	Dietary Fiber (%)
Control	57.75^{d}±0.22	15.80^{a}±0.18	23.35^{a}±0.42	1.01^{c}±0.16	2.10±0.17	–
2.5%PEF	59.77^{c}±0.52	15.27^{b}±0.17	20.48^{b}±0.36	2.29^{b}±0.52	2.19±0.46	0.90^{c}±0.71
5%PEF	62.13^{b}±0.66	14.74^{c}±0.20	17.68^{c}±0.26	3.39^{a}±0.30	2.07±0.03	2.22^{b}±0.29
7.5%PEF	63.40^{a}±0.11	14.59^{c}±0.11	16.18^{d}±0.66	3.22^{a}±0.32	2.61±0.43	4.23^{a}±1.22
P-value	<0.0001	<0.0001	<0.0001	0.0001	0.2270	0.0078
SEM	0.66	0.15	0.83	0.30	0.10	0.54

Note: ^{a,b,c,d} Means in column with no common superscript significant difference (P<0.05)

PEF: purple eggplant flour; SEM: Standard error of the means

Water holding capacity

Water holding capacity of meat and meat product is very important parameter, since retained moisture in the product affects its meat quality and meat production yield. Table 8 showed the water holding capacity of low fat beef patties containing different level of PEF. Compared to control sample, beef patties formulated with PEF at any concentration showed a decreased thawing loss, drip loss and cooking loss ($P<0.05$). Beef patties contained 2.5, 5 and 7% PEF had lower thawing loss (1.23±0.10, 1.08±0.01 and 1.00±0.07%, respectively) than control sample (1.68±0.24%). Drip loss of three levels of PEF sample was lower than control sample (2.81±0.16, 2.48±0.17, 2.41±0.08 and 3.17±0.21% of drip loss, respectively) while 5 and 7.5% PEF were not significantly differences. The 7.5% PEF added beef patties had the lowest in cooking loss percentage (14.56±0.22%) while the highest cooking loss (25.84±0.22%) was found in control sample ($P<0.05$). The lowest moisture retention was observed in control (38.41±1.16%) and concomitantly increased with the addition of PEF (45.03±0.59, 47.70±0.58 and 50.43 ±0.65%, respectively) ($P<0.05$).

Table 8 Water holding capacity of low fat beef patties contained different concentrations of purple eggplant flour

Treatment	Thawing loss (%)	Drip loss (%)	Cooking loss (%)	Moisture retention (%)
Control	1.68^{a}±0.24	3.17^{a}±0.21	25.84^{a}±0.22	38.41^{d}±1.16
2.5%PEF	1.23^{b}±0.10	2.81^{b}±0.16	15.80^{b}±0.29	45.03^{c}±0.59
5%PEF	1.08^{b}±0.01	2.48^{c}±0.17	15.36^{c}±0.19	47.70^{b}±0.58
7.5%PEF	1.00^{b}±0.07	2.41^{c}±0.08	14.56^{d}±0.22	50.43^{a}±0.65
P-value	0.0013	0.0015	<0.0001	<0.0001
SEM	0.08	0.10	1.39	1.36

Note: ^{a,b,c,d} Means in column with no common superscript significant difference ($P<0.05$)

PEF: purple eggplant flour; SEM: Standard error of the means

Cooking characteristics

The cooking characteristics of beef patties extended with or without PEF were depicted in Table 9. Percentage of cooking yield, fat retention, diameter and thickness reduction were measured to determine the influence of adding fiber from PEF on beef patties. The results from this study indicate that the addition of PEF significant ($P<0.05$) affected cooking characteristics of the patties. The control group presented the lowest cooking yield (74.16±0.22%) and was significantly different from the other formulations (84.20±0.29% of 2.5% PEF, 84.64±0.18% of 5% PEF and 85.44±0.22% of 7.5% PEF). The cooking yield of cooked beef patties were significantly increased ($P<0.05$) by the addition of PEF. Increasing the concentration of PEF in the patties increased ($P<0.05$) the fat retention (76.00±0.49% of 2.5% PEF, 77.03±1.10% of 5% PEF and 77.59±1.90% of 7.5% PEF, respectively) and control sample was 72.31±0.67% of fat retention percentage. The diameter reduction of cooked beef patties formulated with PEF was significant decrease when PEF added. Beef patties contained PEF was significantly lower diameter reduction after cooking ($P<0.05$) (16.22±0.15% of 2.5% PEF, 15.74±0.30% of 5% PEF and 11.33±0.47% of 7.5% PEF) than control sample (20.02±0.24%). The highest ($P<0.05$) thickness reduction after cooking were control sample (3.59±0.62%), while cooked beef patties containing PEF exhibited the lowest ($P<0.05$) thickness reduction (2.94±0.71% of 2.5% PEF, 2.84±0.35% of 5% PEF and 2.81±0.31 of 7.5% PEF).

Table 9 Cooking characteristic of low fat beef patties contained different concentrations of purple eggplant flour

Treatment	Cooking yield (%)	Fat retention (%)	Diameter reduction (%)	Thickness reduction (%)
Control	74.16^{c}±0.22	72.31^{b}±0.67	20.02^{a}±0.24	3.59^{a}±0.62
2.5%PEF	84.20^{b}±0.29	76.00^{a}±0.49	16.22^{b}±0.15	2.94^{b}±0.71
5%PEF	84.64^{b}±0.18	77.03^{a}±1.10	15.74^{b}±0.30	2.84^{b}±0.35
7.5%PEF	85.44^{a}±0.22	77.59^{a}±1.90	11.33^{c}±0.47	2.81^{b}±0.31
P-value	<0.0001	0.0023	<0.0001	0.0186
SEM	1.39	0.68	0.93	0.10

Note: ^{a,b,c} Means in column with no common superscript significant difference (P<0.05).
PEF: purple eggplant flour; SEM: Standard error of the means

Textural properties

Food texture plays an important role in influencing the consumers' liking and decision to repurchase. Textural properties for raw and cooked beef patties with different PEF levels (2.5, 5 and 7% PEF) and control sample are shown in Table 10. All of textural properties did not different (P>0.05) among the different beef patties formula in the raw state. There was no significant difference among the treatment group in hardness value. The hardness value of raw beef patties with 2.5% PEF (2.94±0.57 kg) was higher (P>0.05) than control (2.67±0.70 kg) and raw beef patties with 5 and 7.5% PEF (2.38±0.53 kg and 2.85±0.19 kg, respectively). The springiness of raw beef patties with added PEF ranged from 0.76±0.31 to 0.91±0.10. Springiness value increased as the PEF content increased but there was no significant difference for the springiness value in raw beef patties extended with or without PEF (0.90±0.03 of control group). Table 15 also shows the textural properties of cooked beef patties with different amounts of PEF (0, 2.5, 5 and 7% PEF). The firmness value of cooked beef patties with added different level of PEF (0.34±0.05, 0.33±0.02 and 0.33±0.01 kg) had no significant difference when compared with control (0.30±0.06 kg). The cooked beef patties contained the PEF had higher shear force values (2.99±0.23, 2.87±0.06 and 3.01±0.04 kg) than control sample (2.35±0.36 kg).

Table 10 Textural properties of raw and cooked low fat beef patties contained different concentrations of purple eggplant flour

Textural properties	Treatment				P-value	SEM
	Control	2.5%PEF	5%PEF	7.5%PEF		
Raw patties						
Hardness (kg)	2.67±0.70	2.94±0.57	2.38±0.53	2.85±0.19	0.6084	0.15
Springiness	0.90±0.03	0.76±0.31	0.85±0.15	0.91±0.10	0.7564	0.05
Cooked patties						
Firmness (kg)	0.30±0.06	0.34±0.05	0.33±0.02	0.33±0.01	0.6259	0.01
Shear force values (kg)	2.35^{a}±0.36	2.99^{b}±0.23	2.87^{ab}±0.06	3.01^{b}±0.04	0.0177	0.10

Note: ^{a,b} Means in row with no common superscript significant difference (P<0.05).

PEF: purple eggplant flour; SEM: Standard error of the means

Sensory evaluation

Meat quality is important in ensuring consumer satisfaction. The quality grade of meat is determined by an evaluation in terms of palatability factors. The addition of PEF did not affect sensory attributed of cooked beef patties. All data showed that there were no significant differences between all beef patties formulas compared with the control in their tenderness, juiciness, visual appearance, color, odor, texture, taste, overall acceptability and off-flavor (Table 11). A 9-hedonic scale was used which ranged from 9 to 1 which 9 scale of tenderness and juiciness means extremely tender and juicy whereas 1 scale means extremely tough and dry. Where 9 scale means like extremely and 1 means dislike extremely for Appearance, color, odor, texture, taste and overall acceptability. Tenderness and juiciness score, appearance, color, odor, texture, taste and overall acceptability were between 5.54±0.20 to 6.74±0.47, 6.31±0.59 to 7.23±0.64, 5.79±0.78 to 7.01±0.72, 5.38±0.93 to 7.20±0.91, 5.48±0.76 to 6.93±0.77, 6.23±0.92 to 7.13±0.52, 6.84±0.44 to 7.78±0.55 and 6.07±0.64 to 6.63±0.39, respectively, meaning that panelists evaluated all the formulation in acceptable ranges. Rather tenderness and juiciness score increased slightly from 5.54±0.20 to 6.74±0.47 and 6.31±0.59 to 7.23±0.64, respectively due to

addition of PEF prevents moisture loss. The appearance acceptability score of control sample was 6.91±1.16 and beef patties with 2.5, 5 and 7% PEF were 7.01±0.72, 6.33± 0.75 and 5.79±0.78, respectively which had no significantly differences. Color liking score were not significantly different between treatment group (P>0.05) (6.25±1.03 of control, 7.20±0.91 of 2.5% PEF, 6.04±1.01 of 5% PEF and 5.38±0.93 of 7.5% PEF). No significant difference was found in odor intensity scores of beef patties with different PEF levels (6.60± 0.90, 6.23±0.79 and 5.48±0.76) and control sample (6.93±0.77). Control patties had higher acceptance of texture score (7.13±0.52) than beef patties with 2.5, 5 and 7.5% PEF (6.23± 0.92, 6.26±0.65 and 6.33±0.65, respectively) but there was no statistically significant difference for the texture acceptability score in all beef patties. The acceptance of taste score for beef patties with 2.5% PEF (7.78±0.55) was the highest and followed by beef patties with 5% PEF (7.14±0.03), control (7.07±0.57) and 7.5% PEF (6.84±0.44), but did not differ significantly among the treatment (P>0.05). The overall acceptability score for beef patties formulated with 5% PEF (6.63±0.39) were higher than control samples (6.31± 0.43), 2.5% PEF (6.26±0.44) and 7% PEF (6.07±0.64) but did not indicate a significant statistical difference between control and treatment group. Off-flavor intensity of beef patties with different PEF levels was 1.79±0.65 of 2.5% PEF, 1.93±0.48 of 5% PEF and 2.32±0.58 of 7.5% PEF. The off-flavor intensity increased as the PEF content increased but there was no significant difference for beef patties extended with or without PEF (1.34± 0.39 control).

Table 11 Sensory evaluation of low fat beef patties contained different concentrations of purple eggplant flour

Sensory characteristics	Treatment				P-value	SEM
	Control	2.5%PEF	5%PEF	7.5%PEF		
Tenderness	5.54±0.20	5.79±0.94	6.30±0.67	6.74±0.47	0.1706	0.21
Juiciness	6.31±0.59	6.64±0.57	6.96±0.30	7.23±0.64	0.2360	0.17
Appearance acceptability	6.91±1.16	7.01±0.72	6.33±0.75	5.79±0.78	0.3509	0.26
Color liking	6.25±1.03	7.20±0.91	6.04±1.01	5.38±0.93	0.2259	0.31
Odor intensity	6.93±0.77	6.60±0.90	6.23±0.79	5.48±0.76	0.2260	0.26
Acceptance of texture	7.13±0.52	6.23±0.92	6.26±0.65	6.33±0.65	0.3926	0.20
Acceptance of Taste	7.07±0.57	7.78±0.55	7.14±0.03	6.84±0.44	0.1494	0.15
Overall acceptability	6.31±0.43	6.26±0.44	6.63±0.39	6.07±0.64	0.5772	0.13
Off-flavor intensity	1.34±0.39	1.79±0.65	1.93±0.48	2.32±0.58	0.2398	0.17

Note: PEF: purple eggplant flour; Nine point scale for appearance, color, odor, texture, taste and overall acceptability evaluation (1 = dislike extremely, 9 = like extremely) and Nine point scale for tenderness, juiciness and off-flavor (1 = extremely tough, dry and no off-flavor, 9 = extremely tender, juicy and extremely high off-flavor)

Color evaluation

The color of meat products is one of the most significant sensory attributes that affects the consumer acceptance and it is a sign of meat quality and fresh. The appearances of patties, as assessed colorimeter during the 7 day storage period, were presented in Table 12. The L* (lightness) color parameters were determined on raw beef patties at day 0, 1, 3, 5 and 7 of refrigerated storage. At origin, raw beef patties with PEF had significantly lower L* values (40.39±0.32 of 2.5% PEF, 38.70±0.57 of 5% PEF and 37.91±0.52 of 7.5% PEF) than control (41.87±0.37), due to the dark purple color of purple eggplant flour presumably caused the lower L* values of the PEF added samples. On 1st day of storage, the L* values of control (41.69±0.57) and raw beef patties with 2.5% PEF (40.96±0.02) had significantly higher ($P<0.05$) than raw beef patties with 5% (39.13±0.59) and 7.5% PEF (38.63±0.12). On 3rd day of storage, the L* values of control (42.72±0.41) and raw

beef patties with 2.5% PEF (42.96±0.02) were significantly higher (P<0.05) than raw beef patties with 5% (40.91±0.13) and 7.5% PEF (39.83±0.54). On 5th day of storage, the L* values for control (43.07±0.06) and raw beef patties with 2.5% PEF (43.43±0.38) were the highest (P<0.05) followed by beef patties with 5% (41.74±0.24) and 7.5% PEF (40.64±0.30). On 7th day of storage, the L* values for control (45.07±0.44) was the highest (P<0.05) followed by beef patties with 2.5% PEF (43.69±0.27), 5% PEF (42.28±0.26) and 7.5% PEF (41.19±0.55). The L* values had increased (P<0.05) progressively with the storage time of beef patties formulated with and without PEF. Less change of L* values also was observed in PEF treated samples.

The redness (a* color) parameters were determined on raw beef patties at day 0, 1, 3, 5 and 7 of refrigerated storage (table 12). Initially control group (day 0) (15.70±0.28) was significantly higher than beef patties with 2.5% PEF (12.69±0.15), 5% PEF (10.32± 0.26) and 7.5% PEF (8.28±0.54). On 1st day of storage, the a* value of control (14.79± 0.65) was significantly higher (P<0.05) than beef patties with 2.5% PEF (12.11±0.29), 5% PEF (9.90±0.13) and 7.5% PEF (7.86±0.13), respectively. On 3rd day of storage, the a* value of control (12.56±0.12) was significantly higher (P<0.05) than beef patties with 2.5% PEF (9.67±0.65), 5% PEF (8.98±0.65) and 7.5% PEF (7.16±0.08). On 5th day of storage, control patties (10.32±0.31) had significantly higher (P<0.05) a* value than beef patties prepared from 2.5% PEF (8.50±0.55), 5% PEF (8.40±0.25) and 7.5% PEF (6.98±0.09). On 7th day of storage, control patties (8.91±0.27) had significantly higher (P<0.05) a* value than beef patties contained 2.5% PEF (8.07±0.34), 5% PEF (7.32±0.12) and 7.5% PEF (6.68±0.07). The a* value had decreased (P<0.05) during storage in all patties, the rate of the change in a* value was lower when added PEF concentration was higher.

Table 12 showed the yellow color (b* value) of low fat beef patties contained different concentrations of PEF at day 0, 1, 3, 5 and 7 of refrigerated storage. At day 0, An increased in PEF concentration has been shown to increase the b* value (5.94±0.49 of control, 7.84±0.32 of 2.5% PEF, 8.92±0.20 of 5% PEF and 9.08±0.40 of 7.5% PEF). On 1st day of storage, the b* value of control (6.25±0.64) was significantly lower than raw beef patties with 2.5% PEF (7.55±0.46), 5% PEF (8.19±0.50) and 7.5% PEF (8.69±0.43).

On 3rd day of storage, control patties (6.25±0.56) had significantly lower (P<0.05) a* value than beef patties prepared from 2.5% PEF (7.95±0.55), 5% PEF (8.20±0.09) and 7.5% PEF (8.38±0.41). On 5th day of storage, the b* values for control (6.01±0.54) was the lowest (P<0.05) followed by beef patties with 2.5% PEF (7.62±0.41), 5% PEF (8.68± 0.36) and 7.5% PEF (8.93±0.75). On day 7 of storage, the b* values for control (6.14±0.18) was lower (P<0.05) than beef patties with 2.5% PEF (7.70±0.25), 5% PEF (8.52±0.06) and 7.5% PEF (8.00±0.77). The lowest b* values were observed in control and concomitantly increased with the addition of PEF (P<0.05) and reached the maximum at 7.5% PEF formulated patties, However, the b* value of all sample during over a period storage were not significant.

Lipid oxidation

The oxidative stability of raw low fat beef patties contained different concentrations of PEF was evaluated during 7 days of refrigerated storage expressed as μM MDA/g (Table 12). Thiobarbituric acid reactive substances (TBARS) were used as an indicator of lipid oxidation. On 0th day of storage, no significantly differences were observed between the TBARS values of raw beef patties with PEF (0.05±0.01 μM MDA/g of 2.5% PEF, 0.06±0.01 μM MDA/g of 5% PEF and 0.05±0.02 μM MDA/g of 7.5% PEF) and control (0.06±0.02 μM MDA/g). On 1st day of storage, the TBARS values of control (0.51±0.06 μM MDA/g) and raw beef patties with 2.5% PEF (0.45±0.08 μM MDA/g) were significantly higher (P<0.05) than raw beef patties with 5% PEF (0.21±0.10 μM MDA/g) and 7.5% PEF (0.06±0.03 μM MDA/g). On 3rd day of storage, the TBARS values of control was the highest (1.80±0.15 μM MDA/g) followed by beef patties with 2.5% PEF (1.23±0.28 μM MDA/g), 5% PEF (0.95±0.12 μM MDA/g) and 7% PEF (0.41±0.16 μM MDA/g) respectively. On 5th day of storage, the TBARS values of control (4.27±0.44 μM MDA/g) was the highest (P<0.05) followed by raw beef patties with 2.5% PEF (2.38±0.24 μM MDA/g), 5% PEF (2.01±0.04 μM MDA/g) and 7.5% PEF (1.89±0.05 μM MDA/g). On 7th day of storage, control sample (5.86±0.46 μM MDA/g) was the highest TBARS values followed by raw beef patties with 2.5% PEF (3.60±0.42 μM MDA/g), 5% PEF (3.09±0.59 μM MDA/g) and 7.5% PEF (2.28± 0.09 μM MDA/g). TBARS values generally increased in meat product during storage. Results

from the TBARS analysis in this part of the study showed that the raw patties with PEF had significantly lower TBA values than the control group during storages at 1, 3, 5 and 7 day respectively ($P<0.05$), indicating the significant antioxidant effect of PEF on the beef patties. The maximum value of TBARS reached by the raw control patties was 5.86 μM MDA/g.

Table 12 Effects of storage time on changes of color nuances of low fat beef patties contained different concentrations of purple eggplant flour

	Storage time (day)	Treatment			
		Control	2.5%PEF	5%PEF	7.5%PEF
L*	Day 0	41.87^{Ac}±0.37	40.39^{Bd}±0.32	38.70^{Cc}±0.57	37.91^{Cc}±0.52
	Day 1	41.69^{Ac}±0.57	40.96^{Ac}±0.02	39.13^{Bc}±0.59	38.63^{Bc}±0.12
	Day 3	42.72^{Ab}±0.41	42.96^{Ab}±0.02	40.91^{Bb}±0.13	39.83^{Cb}±0.54
	Day 5	43.07^{Ab}±0.06	43.43^{Aa}±0.38	41.74^{Ba}±0.24	40.64^{Ca}±0.30
	Day 7	45.07^{Aa}±0.44	43.69^{Ba}±0.27	42.28^{Ca}±0.26	41.19^{Da}±0.55
a*	Day 0	15.70^{Aa}±0.28	12.69^{Ba}±0.15	10.32^{Ca}±0.26	8.28^{Da}±0.54
	Day 1	14.79^{Ab}±0.65	12.11^{Ba}±0.29	9.90^{Ca}±0.13	7.86^{Da}±0.13
	Day 3	12.56^{Ac}±0.12	9.67^{Bb}±0.65	8.98^{Bb}±0.65	7.16^{Cb}±0.08
	Day 5	10.32^{Ad}±0.31	8.50^{Bc}±0.55	8.40^{Bb}±0.25	6.98^{Cb}±0.09
	Day 7	8.91^{Ae}±0.27	8.07^{Bc}±0.34	7.32^{Cc}±0.12	6.68^{Db}±0.07
b*	Day 0	5.94^{C}±0.49	7.84^{B}±0.32	8.92^{A}±0.20	9.08^{A}±0.40
	Day 1	6.25^{C}±0.64	7.55^{B}±0.46	8.19^{AB}±0.50	8.69^{A}±0.43
	Day 3	6.25^{B}±0.56	7.95^{A}±0.55	8.20^{A}±0.09	8.38^{A}±0.41
	Day 5	6.01^{C}±0.54	7.62^{B}±0.41	8.68^{A}±0.36	8.93^{A}±0.75
	Day 7	6.14^{B}±0.18	7.70^{A}±0.25	8.52^{A}±0.06	8.00^{A}±0.77
MDA (μM MDA/g)	Day 0	0.06^{d}±0.02	0.05^{d}±0.01	0.06^{d}±0.01	0.05^{d}±0.02
	Day 1	0.51^{Ad}±0.06	0.45^{Ad}±0.08	0.21^{Bd}±0.10	0.06^{Cd}±0.03
	Day 3	1.80^{Ac}±0.15	1.23^{Bc}±0.28	0.95^{Bc}±0.12	0.41^{Cc}±0.16
	Day 5	4.27^{Ab}±0.44	2.38^{Bb}±0.24	2.01^{Bb}±0.04	1.89^{Bb}±0.05
	Day 7	5.86^{Aa}±0.46	3.60^{Ba}±0.42	3.09^{BCa}±0.59	2.28^{Ca}±0.09

Note: ^{a,b,c,d,e} Difference letters indicate a significant difference between storage time

^{A,B,C,D} Difference letters indicate a significant difference between treatment

PEF: purple eggplant flour

CHAPTER V

CONCLUSION

Discussion

Chemical composition

1. Chemical composition of purple eggplant flour (PEF)

This study found that PEF had moisture content about 10.79±0.14% and 10.48± 0.42% of protein. Protein content that we obtained was found to be lower than the result of protein content reported by Uthumporn et al. (2016), which was about 15.75±0.05%. This may be due to the addition of different fertilizer to soil in Malaysia and fertilizer can increase the protein content of plants. PEF contained a lower amount of fat (1.87±0.05%) compared to corn grits (2.33%), wheat flour (2.15%) and soybean flour (10.10 ± 0.06%) (Dehghan-Shoar, Hardacre and Brennan, 2010; Ndife, Abdulraheem and Zakari, 2011). Dietary fibers of PEF (37.86±0.63%) were higher than peeled citrus (1.29±1.34%) (Gorinstein et al., 2001). The in-soluble dietary fiber (IDF) was higher in the PEF (33.83± 0.29%) than that in mango peel (32.1±1.34%) (Ajila, Leelavathi and Rao, 2008) and oat bran (8.5±0.38%) but lower than wheat bran (44.8±0.45%) (Talukder and Sharma, 2010). The soluble dietary fiber (SDF) in PEF was 4.03±0.57%, which is lower than the values reported by Uthumporn et al. (2016) (5.68±12.28%). The chemical compositions of eggplant were influenced by genotype, environment and soil type and growth as well as by cultivation systems and addition of fertilizer (Niño-Medina et al., 2017; Uthumporn et al., 2016).

2. Chemical composition of beef patties formulated with different levels of purple eggplant flour

Composition of meat products is influenced by different level of PEF. The differences between moisture, protein, fat, ash, carbohydrate and dietary fiber content of raw low fat beef burgers were statistically significant ($P<0.05$). The moisture content of patties samples increased ($P<0.05$) with increasing amounts of PEF. Similar results were obtained by Turhan, Sagir and N. S. Ustun (2005) who found that the moisture content of

low fat beef patties increase with increase hazelnut pellicle flour from 64.45 to 66.72%. The results of this study were consistent with those obtained by Choi et al. (2012) for the addition of *Laminaria japonica* to reduced fat chicken patties and Desmond, Troy and Buckley (1998) for the addition of oat fiber to low-fat beef burgers. These studies showed similarly that natural source dietary fiber increased the moisture content of meat product. In the other hand, the protein contents of beef patties slightly decreased as the PEF content increased ($P<0.05$), and this could be attributable to the increase in moisture content. Similar results were reported by Park et al. (2016) in pork patties added with buckwheat. The fat values of patties samples decreased ($P<0.05$) with increasing amounts of PEF. This result was caused by the initial formation of control groups having more fat contents compared to the other groups when added with of PEF. These results agreed with Khalil (2000) who reported similar result for reduced fat supplemented with modified corn starch and water replaced the low fat beef patties. Beef patties contained PEF had ash content higher ($P<0.05$) than control sample due to the high mineral content in eggplant such as phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), and zinc (Zn) (Raigón et al., 2008). Choi et al. (1999) reported that the moisture and ash content of bread increased with the addition of *Angelica keiskei Koidz* flour. The increasing amount of dietary fiber resulted in an increase the water absorption capacity of batter since cellulose in fiber has a lot of hydroxyl (OH) groups. These OH groups form strong hydrogen bonds with water molecules (Uthumporn et al., 2015).

Water holding capacity

Thawing loss of raw beef patties contained PEF had lower than control sample. López-López et al. (2010) found that beef patties made with Wakame seaweed presented lower ($P<0.05$) thawing loss (1.23%) compared to control sample (3.56%). Drip loss with PEF was lower compared to control sample. Similaly, Berry and Wergin (1993) and Khalil (2000) have reported that higher moisture retention in uncooked beef patties when fat was replaced with modified pregelatinized potato starch and modified cornstarch, respectively. According to PEF contains 38.41%, the high dietary fiber content of PEF could be the most probable reason to increase WHC of beef patties. The cooking loss of patties samples decreased ($P<0.05$) with increasing amounts of PEF while the highest cooking

loss was found in control sample (25.84±0.22%). Soltanizadeh and Ghiasi-Esfahani (2015) observed that adding aloe vera decreased the cooking loss of beef patties due to attributed to the higher water holding capacity and moisture retention of aloe vera during cooking. The lowest moisture retention was observed in control and concomitantly increased with the addition of PEF. Enhanced levels of PEF incorporation as a fat replacer resulted in a rising trend in water holding capacity of low fat beef patties because of the ability of PEF to absorb and bind more water. This ability prevents moisture loss in meat products. Therefore, this result showed that the addition of PEF to low fat beef patties resulted in reduction of drip loss, thawing loss and cooking loss.

Cooking characteristics

Yield of meat and meat product are connected with fat and water retention (Aleson-Carbonell et al., 2005). The cooking yield of cooked beef patties were increased ($P<0.05$) by the addition of PEF. Similar trend was observed by Naveena et al. (2006) for chicken patties extended with finger millet (*Eleusine coracana*) flour (83.99 to 84.95%, cooking yield). Increasing the concentration of PEF in the patties increased ($P>0.05$) the fat retention. According to Kastner and Felicio (1980), grinding of meat during burger processing results in a tender product due to the breakdown of the myofibrils and connective tissue which however promotes weight loss during the cooking process. Alakali, Irtwange and Mzer (2010) reported significant ($P>0.05$) increases in fat retention for beef patties formulated with different levels of bambara groundnut (*Vigna subterranean* L.) seed flour. The difference in cooking yield and fat retention between samples might be due to water evaporation and lipid migration in beef patties during the cooking process (Sánchez-Zapata et al., 2010). Hawashin et al. (2016) reported the moisture and fat retention of patties may be attributed increase the water absorption capacity, gelatinization and swelling of starch and fiber. Other researchers have had similar findings, patties is more cooking yield, moisture retention, and fat retention when formulated with ground poppy seed (Gök et al., 2011), tiger nut fiber (Sánchez-Zapata et al., 2010) bambara groundnut seed flour (Alakali, Irtwange and Mzer, 2010) and inner pea fiber (Anderson and Berry, 2001).

Dimensional changes are important in maintaining quality standards of burger linked to potential negative reactions of consumer due to the negative image of excessive added water. Therefore, the impact of added ingredients in dimensional changes must be evaluated. Cooked beef patties contained PEF incurred less diameter reduction and thickness reduction ($P>0.05$) than control sample. The reduction in diameter and thickness of beef patties during cooking could be improved due to the binding and stabilizing property of PEF, which held the meat particles together and resisted changes in the shape of the product. In a similar study, Choi et al. (2012) reported that adding *Laminaria japonica* powder to pork patties decreased diameter reduction and thickness reduction. The differences in the diameter and thickness reduction could be related to water and fat absorption depress of the non-meat ingredient used. The reduction in diameter is the result of the denaturation of meat product with the loss of water and fat (Besbes et al., 2008; López-Vargas et al., 2014; Farouk, Hall and Swan, 2000).

Textural properties

The addition of PEF did not affect sensory attributed of cooked beef patties. Data showed that there were no significant differences between all beef patties formulas compared with the control (Table 10). The hardness of raw beef patties with 2.5% PEF (2.94±0.57 kg) was the highest but no significant differences on hardness evaluation entire the experiment. Reinbach et al. (2007) found significant differences on hardness value of pork patties treated with flour. The springiness was no significant difference raw beef patties with PEF and control. Another study, López-Caballero et al. (2005) reported that the texture (hardness, cohesiveness, adhesiveness, gumminess and chewiness) of fish patties with addition of dry powdered chitosan did not change in day 0. According to results featured by Keenan et al. (2014) fat replacement in meat products may modify texture parameters compared to control. The results of texture parameter are very dependents on the type of the fiber used (López-Vargas et al., 2014).

The differences between firmness values were not significantly different but shear force values of cooked low fat beef patties were significantly different. These results may indicate that the addition of PEF could be useful for manufacturing reduced fat patties, because adding PEF can be used to change the physiochemical characteristics of

the patties equivalent to control sample. Brewer (2012) reported that, starches, lipids and proteins incorporation can be used as effective fat replacers in low fat ground beef patties because starch improves the textural characteristics of the product by modified physical or chemical treatments and acts as a versatile food ingredient. Therefore, the starch is commonly utilized in the food industry. Some of the commercial low-fat formulations were made with carrageenan, oat bran, soy and starch (Brewer, 2012).

Sensory evaluation

Rather tenderness and juiciness score increased slightly from 5.54±0.20 to 6.74±0.47 and 6.31±0.59 to 7.23±0.64, respectively but did not differ significantly among the treatment (P>0.05). The tenderness and juiciness score of low-fat beef patties with PEF were comparable with a high-fat control. This might be due to the relatively water holding capacity and oil-holding capacity of PEF, which might have resulted in the patties were more tender and juicy. Furthermore, Feiner (2006) reported that the wheat fiber is neutral in taste and help to retain moisture and fat leading to producing of a more succulent and juicy meat product. The appearance acceptability score of control and beef patties with PEF were not significantly different. Similarly, Yıldız-Turp and Serdaroglu (2010) reported that the appearance had no significant differences between beef patties with and without plum puree. Beef patties with 2.5% PEF (7.20±0.91) had highest color liking score. The appearance acceptability and color liking score of patties prepared by PEF extenders were comparatively lower because the addition of PEF decreased the lightness of the beef patties and also affected the overall acceptability. Font-i-Furnols and Guerrero (2014) reported that dark and dry appearance products are often rejected by consumers and cause revenue loss to the meat industry. No significant difference was found in odor intensity scores between of all beef patties sample. Akarpat, Turhan and Ustun (2008) found no significant differences (P>0.05) in odor scores between beef patties made with nettle (6.42±0.13), lemon balm extract (6.33 0.18) and control (6.24±0.15). The odor intensity score was higher (P<0.05) in the beef patties with myrtle (7.03±0.20) and rosemary extracts (6.82±0.15). The off-flavor intensity increased as the PEF content increased but there was no significant difference for the off-flavor intensity in beef patties extended with or without PEF (1.34±0.39 control). This result indicates that the increased

concentration of PEF influenced off-flavor and taste due to bitter taste of eggplant. The bitter taste is mainly due to the presence of saponins and glycoalkaloids. However, the addition of PEF to low-fat beef patties results in acceptable and desirable sensory properties, there were no significant difference from the control group in overall acceptability.

Color evaluation

PEF caused a reduction in L* values ($P<0.05$) of low fat beef patties (Table 12). The higher level of PEF was correlated to darker color of the products, due to the dark purple color of purple eggplant presumably causing the lower L* and a* values of the PEF added samples. Similar finding was also reported that the addition of the higher PEF on cookies led to a reduction of L* values (Uthumporn et al., 2015). The L* values increased ($p<0.05$) progressively with the storage time of all beef patties. Less change of L* values also was observed in PEF treated samples. Bis-Souza, Henck and Barretto (2018) showed similar results when they replaced the dietary fiber in low-fat beef burger with inulin and fructooligosaccharide. After 90 days of storage under -20°C, the L* value of 3% inulin was significantly higher ($P<0.05$) than the other treatments. While a* value decreased ($p<0.05$) during storage in all patties, the rate of the change in a* value was lower when PEF concentration was higher. Candogan (2002) reported similar results, for beef patties formulated with different level of tomato paste and this could be explained that the incorporation of tomato paste was shown to be effective in retarding color change or pigment oxidation. The lowest b* values were observed in control and concomitantly increased with the addition of PEF ($P<0.05$) and reached the maximum at 7.5% PEF formulated patties, however, the b* value of all sample during storage were not significant ($P>0.05$). Al-Juhaimi et al. (2016) reported that b* values of beef patties increased ($P<0.05$) with addition of Moringa seed flour and b* values of in all of beef patties were significantly increased during the storage period.

Lipid oxidation

Oxidation is one of the major causes of deterioration of fats and oils leading to the development of rancid odors and taste, and also causing a reduction in the shelf life of the fat or oil (Moure et al., 2001). The thiobarbituric acid reactive substance (TBARS) value is a sensitive test for the decomposition products of highly unsaturated fatty acids which

do not appear in peroxide value determination (Melton, 1983). This study investigated the addition of PEF as natural antioxidants source to improve the oxidative stability of beef patties. TBARS values generally increased in meat product during storage. Results from the TBARS analysis in this part of this study showed that the raw patties extended with PEF had significantly lower TBA values than the control group during storages at 1, 3, 5 and 7 days, respectively ($P<0.05$). The maximum value of TBARS reached by the raw control patties was 5.86 μM MDA/g. Thus, the addition of PEF to patties products could inhibit lipid oxidation and extend the shelf life of these products under cold storage conditions. On day 3 of storage day, the TBARS value (1.80 μM MDA/g sample) of the control patties was higher than the limit (1.59 μM MDA/g sample) which may have a negative effect on consumer health (Ozer and Sariçoban, 2010). However, the TBARS values (0.41 to 1.23 μM MDA/g sample) in day 3 of storage day of all PEF containing patties were consistently within the acceptable limit indicating the significant antioxidant effect of PEF on the beef patties. Previous studies have established that extracts from purple eggplant peels exhibit high capacity to scavenge of free radicals and prevent propagation of lipid oxidation (Uthumporn et al., 2016). Nasunin is a major component of anthocyanin pigment of eggplant peels is one phenolic compound implicated in both inhibition of hydroxyl radical generation and superoxide scavenging activity (Noda et al., 2000).

Conclusion

The results of this study indicated that substitution of fat with PEF in low fat beef patties has a significant effect on the quality of the samples. PEF is a good source of dietary fiber for use as a functional ingredient in beef patties. Substitution of fat with PEF can also improve product quality. The addition of PEF reduced the thawing loss, drip loss and cooking loss. Therefore, the low fat beef patties containing PEF had increased moisture retention, fat retention and cooking yield of product. Moreover, PEF improved the reduction in diameter and thickness and textural properties. Although beef patties formulated with PEF in beef patties had lower L*and higher a* than control samples, addition of PEF did not significantly affect to the sensory scores of the patties as perceived by the consumer.

The addition of PEF improved color stability of raw beef patties during refrigerated storage. Similarly, the use of PEF appeared to reduce lipid oxidation of raw beef patties during refrigerated storage. Thus, PEF could be added to enhance the nutritional value and quality of beef patties with improved water holding capacity and delayed lipid oxidation. However, the dark color of PEF is a big obstacle for addition of PEF to beef burgers. Based on the results, the addition of 2.5, 5 and 7.5% PEF improved the quality characteristics of low-fat beef patties that were similarly to the control patties containing high fat content.

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APPENDIX

APPENDIX A

Low fat beef patties sensory evaluation form

Sample number.....

Instruction:

1. Low fat beef patties will be evaluated. Please mark through the line " —|— " to record your evaluation. Please evaluate near the center of the Low-fat beef patties

2. Please rinse your mouth with water before starting. You can rinse at any time during the test if you need to.

3. Please taste the samples according to the number on each page.

4. Do NOT go back and re-taste the samples once you have turned the page.

5. You can eat a saltine cracker between samples.

6. Rinse your mouth with water between samples.

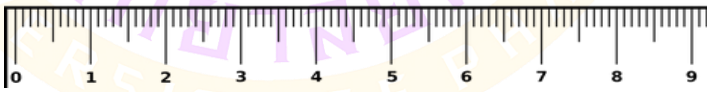
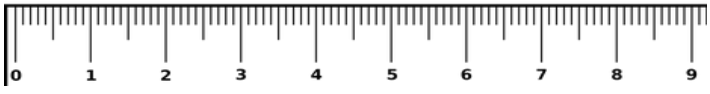
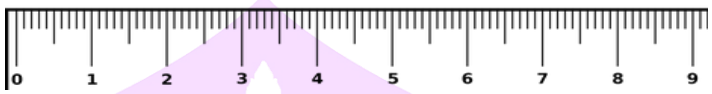
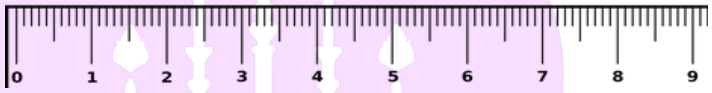
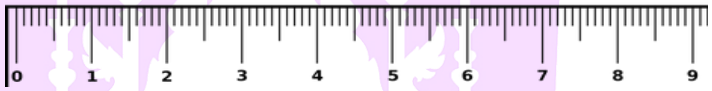
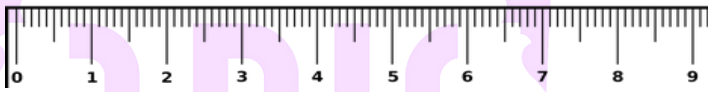
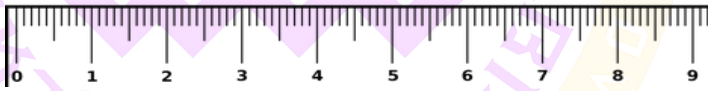
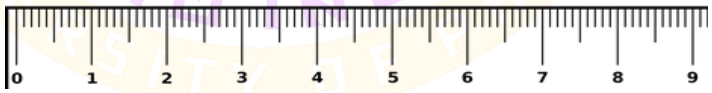
Sensory characteristics	Satisfaction level
1. Appearance	 Dislike extremely Like extremely
2. Color	 Dislike extremely Like extremely
3. Odor	 Dislike extremely Like extremely

Table (cont.)

Sensory characteristics	Satisfaction level
4. Off–flavor	 no off–flavor extremely high off–flavor
5. Tenderness	 extremely tough extremely tender
6. Juiciness	 extremely dry extremely juicy
7. Taste	 Dislike extremely Like extremely
8. Texture	 Dislike extremely Like extremely
9. Overall acceptability	 Dislike extremely Like extremely

VITA

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