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Effect of fat replacers on quality characteristics of low fat meat products: a review

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ABSTRACT

High animal fat intake is associated with an increased risk for obesity, hypertension, cardiovascular diseases, some types of cancer and coronary heart diseases. Reduction of fat in meat products leads to firmer, more rubbery, less juicy, darker in colour, more costly and less acceptable in terms of skin formation, mouth feel, and processing yield. Manufacturers have introduced several modifications in an attempt to offset the detrimental effects of reducing the fat level. These modifications include the use of fat replacers that could help to improve the quality of reduced fat meat products. Fat is replaced in meat product by reformulating the meat product with lipid-, protein- or carbohydrate-based ingredients. The direct replacement of fat with non-meat ingredients is an attractive alternative approach to fat reduction due to the excellent functional and nutritional properties that non-meat ingredients impart.
Keywords: Fat replacers; Low-fat; Meat product; Quality properties; hypertension; obesity

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INTRODUCTION

Meat products are complex multiphase systems containing lean meat, water, fat, condiments and some other additives and rich in essential human elements including protein, fat, carbon polymers, vitamins and minerals **(Guo et al., 2023).** Fats are of vital importance as a source of energy and essential fatty acids, and as carriers of fat soluble vitamins. Also, fats play vital functional and sensory roles in various food products, fats interact with other ingredients to develop texture and mouth feel **(Vural et al., 2004).** In meat products, fat plays important roles in stabilizing meat emulsions, reducing cooking loss, improving water holding capacity and providing flavor, juiciness and a desirable mouth feel **(Yang et al., 2007).** High fat contents, in particular animal fats, provide high amounts of cholesterol and saturated fatty acids **(Özvural and Vural, 2008).**

Therefore, high animal fat intake is associated with an increased risk for obesity, hypertension, cardiovascular diseases, some types of cancer and coronary heart diseases. **(Moon et al., 2008; Oliveira et al., 2022).**

Fat reduction in meat products results in harder, more rubbery, less juicy, darker in color, more expensive, and less acceptable skin formation, mouth feel, and processing yield (**Cengiz and Gokoglu, 2005).** Other technological problems like reduction in particle binding, rubbery skin formation, soft and mushy interiors, reduced cook yields, excessive purge and shortened shelf life are also associated with a reduction in fat levels **(Mallika et al., 2009).**
Manufacturers have introduced several modifications in an attempt to offset the detrimental effects of reducing the fat level, these modifications include the use of fat replacers that could help to improve the quality of reduced fat meat products **(Piñero et al., 2008; Ren et al., 2022).**

1. Fat replacers: definition and classification

A fat replacer is an ingredient that can be used to provide some or all of the functional properties of fat while providing fewer calories than the fat being replaced **(Omayma et al., 2007).** One of the approaches to produce low-fat meat products is the replacement of fat with non-meat ingredients **(Candogan and Kolsarici, 2003).** Fat replacers in meat products are ingredient that contribute a minimum of calories to formulated meat and do not dramatically alter organoleptic and processing properties **(Jalal et al., 2015).** Animal fat can be replaced with lipid-, protein- or carbohydrate-based ingredients, individually or in combination. Fat replacers represent a variety of chemical type with diverse functional and sensory properties and physiological effects **(Akoh, 1998).**

Many non-meat ingredients such as dietary fibre **(Garcia et al., 2002),** isolated soy protein **(Cengiz and Gokoglu, 2005) ,** carrageenan **(Candogan and Kolsarici, 2003),** water **(Chang and Carpenter, 1997)**,Whey powder **(Serdarğlu, 2006)**, plant oil **(Choi et al., 2010),** oat fiber **(Hughes et al., 1997)** and carbohydrates **(Yang et al., 2007)** have been added to different meat products to counteract the problems caused by fat reduction. The different approaches to replacing animal fat used in meat products with non-animal fat ingredients based on their physical forms during processing. Six different physical forms to replace the fat are categorized as 1) powder, 2) paste, 3) plant oils, 4) combinations of dietary fiber with animal protein/ skin or plant oils, 5) pr-treated fat replacer, and 6) emulsion gels and oleogel **(Asyrul-lzhar et al., 2022)** Fat replacers are generally categorized into two groups: fat substitutes and fat mimetics.

Fat substitutes are macromolecules that physically and chemically resemble triglycerides and which theoretically replace the fat in foods on a one to one, gram for gram basis. Fat substitutes are either chemically synthesized or derived from conventional fat and oil by enzymatic modification. Many fat substitutes are stable at cooking and frying temperatures **(Akoh, 1998; Ognean et al., 2006).**

Fat mimetics are substances that imitate organoleptic or physical properties of triglycerides but which cannot replace fat on a one to one, gram for gram basis. Fat mimetics, often called protein or carbohydrate-based fat replacers, are common food constituents, e.g., starch, cellulose, but may be chemically or physically modified to mimic the function of fat (Ognean et al., 2006; Omayma et al., 2007). The caloric value of fat mimetics ranges from 0-4 kcal/g. Fat mimetics generally absorb a substantial amount of water. However, fat mimetics are not suitable for frying because they bind excessive water and are subjected to denature process or caramelization at high temperatures, however many of them are suitable for baking **(Akoh, 1998; Ognean et al., 2006).**

2. Function properties of fat replacers

Techno-functional properties are defined as the ability to form and/ or stabilize networks (gels and films), emulsions and solutions in addition to oil and water holding capacities **(Munialo and Vriesekoop, 2023).** Function properties of the meat system are primarily dependent on the interaction of protein with other components such as (protein-water, protein-lipid and protein-protein) which have a direct impact on how well the meat system binds water, stabilizes fat and produces desirable sensory textural properties and cohesion **(Shand et al., 1993; Mallika et al., 2009).** In meat products, there are two types of binders according to their functional properties. The first is used in formed products to bind separate meat pieces, but the second type is used to increase water-binding capacity. Therefore, the second type is important in the formulation of low-fat meat products **(Giese, 1992).**

Nonaka (1997) mentioned that plant derived carbohydrates are often effective in low or reduced fat formula, these carbohydrates are hydrophilic due to the large number of hydroxyl groups available to bind with water molecules, creating a carbohydrate water network that can mimic the texture of fat. The direct replacement of fat with non-meat ingredients is an attractive alternative approach to fat reduction due to the excellent functional and nutritional properties that non-meat ingredients impart (Yang, 2007). Table (1) lists the general functions of fat replacers in meat products (Ognean et al., 2006).

Table (1) Functions of fat replacers in meat products (Ognean.et al.,2006).

Specific application	Fat replacer	General functions
Processed meat Products	Lipid based as Vegetable oils like sunflower and olive oil	Emulsify,texturize, provide monthfeel
	Carbohydrate based as Dietary fibres and modified or resistant starches Corn , wheat, potato, rice, carrageenan	Increase water holding capacity, texturize, provide mouthfeel, icrease viscosity
	Protein based as whey protein, wheat flour, milk powder, eggs	Stabilize, Texturize, provide mouthfeel, emulsify

3. Effect of fat replacers on processing and textural properties

Cooking characteristics such as cooking loss, diameter reduction and water retention are some of the most important factors for food industry to predict the characteristics of products during and after cooking **(Dias et al., 2022).** In meat products, one important attribute is the ability to hold moisture and other juices in the product before and after treatment **(Yang et al., 2007).** The meat and meat products tend to shrink during the cooking process, due to the denaturation of meat protein with loss of water and fat, and the cooking loss depends on the ability of the gel matrix to immobilize fat and water in finely comminuted meat products **(Varga-Visi and Toxanbayeva 2017).**

Starch possessed very good functional characteristics such as improved moisture retention, water holding capacity, gelation ability and emulsion stability **(Serdaroglu and Degirmencioglu, 2004). Osman et al., (2022)** found that acetylated corn starch enhanced the thickness, moisture retention, and sensory attributes of beef patties. and it also reduced the cooking loss diameter reduction rate and dimensional shrinkage of the patties. Moreover the patties containing 15% acetylated corn starch showed a microstructure similar to that containing 15% animal fat as examined by scanning electron microscopy. **Turhan et al., (2005)** studied the effect of hazelnut pellicle on cook loss and dimensional changes of beef burgers. They found that the highest cook loss was from the control beef burger sample (20% fat), due to high loss of fat and moisture during cooking, while the cook losses of the samples decreased with more hazelnut pellicle addition. Also control beef burgers showed more reduction in diameter by cooking as compared to hazelnut pellicle added beef burgers.

The water holding capacity (WHC) is the ability of meat to hold its own or added water during the application of any force and is considered one of the very important technological properties of meat that affects tenderness, juiciness, thawing drip and cooking yield of meat and meat products. The natural bio-polymers, cereal flours, dietary fibers and proteins reduce fat content and enhance the oil and water holding capacity of meat products **(Guo et al, 2023).** Proteins and hydrocolloids are the ingredients that have found potential use in manufacturing low-fat meat products **(Youssef and Barbut., 2009).** Moreover hydrocolloids with characteristics in building texture, emulsification and stability are of great interest in low fat processed meat areas due to their ability to bind water and form gel **(Ren et al., 2022).** Carrageenan and pectin are some of hydrocolloids that have been studied in low fat meat products **(Candogan and Kolsarici., 2003).** The ability of carrageenan to form a gel in meat products has been proven to give a range of advantages by increasing yield, consistency, sliceability and decreasing purge, fat content. **(Jalal et al., 2015).** The batter process yields and emulsion stability and less purge were observed with increasing carrageenan concentration, also the treatment group showed higher (WHC) than a low-fat control (LFC) and lower WHC than HFC. So with increasing carrageenan concentration, WHC increased and penetrometer value decreased in low fat frankfurters **(Candogan and Kolsarici, 2003).** According to **Serdaroglu and Degirmenciogiu (2004),** the meat balls which made from beef and containing corn flour increased cooking yield and fat retention and no effect on reduction in diameter, in addition, the corn flour reduced shrinkage in meat balls formulated and increased moisture retention.

The main concern for quality parameters regarding emulsified meat products with low fat content is maybe not technological, but rather the consumers concern about unacceptable texture and taste. Gel stability may not be a problem when fat content is reduced without addition of an excess amount of water, because meat protein can form a strong gel with less fat , but in this case the product can be drier, firmer and more rubbery than traditional control . A possible reason for too tough consistence of the formed gel is that there are less fat globules present inside the cavity of meat protein network to soften it **(Vargra-Visi and Toxanbayeva, 2017).** Several studies have examined the addition of emulsion gels to meat products as fat substitutes. **Ferreira et al, (2022)** used olive oil and sunflower oil hydrogel emulsion as fat replacers in goat meat burgers. Results indicated that the use of hydrogel emulsion in the burgers allows us to obtain reduced fat burgers and that the fat replacement did not cause major changes in its quality either as raw or cooked burgers. The use of emulsion gels prepared with chia mucilage and olive oil as fat replacer in beef patties was found to positively influencing the cooking characteristics of the products , improving the cooking yield and liquid retention **(Liu et**

al., 2022). Choi et al., (2009) observed that the meat batters had lower cooking loss and batter emulsion stability when the meat batter supplemented with rice bran and one of vegetable oil as olive, corn, soybean, canola or grape seed at compared with the control sample which containing 30% fat.

Evaluation of textural characteristics of low-fat sausage with added hydrated oatmeal and tofu as texture-modifying agents is carried out using texture profile analysis (TPA), the textural parameter of hardness, cohesiveness, springiness, gumminess and chewiness were measured. The addition of Hydrated oatmeal or tofu into low fat sausage would improve their flavor and textural attributes compared to control sausage without texture-modifying agents. The control sausage (4% fat) had highest hardness rating amongst the sausage samples which prepared with added hydrated oatmeal or tofu and the hardness of the sausage samples gradually decreased with the increasing addition of hydrated oatmeal. The addition of hydrated oatmeal or tofu is useful in preparing a low fat sausage with softer textural properties **(Yang et al., 2007).** The effect of fat level (5,12 and 30%) and maltodextrin on the function properties of frankfurters were investigated by **Crehan et al. (2000)** Results showed that The maltodextrin addition caused decrease in cook loss of frankfurters no significant difference in hardness, gumminess and chewiness value when maltodextrin was present in the reduced fat (5 and 12%) frankfurters were observed. Overall texture and acceptability were unaltered by maltodextrin. The results indicate that maltodextrin can be used as suitable fat replacer, decreasing cook loss and maintaining a number of textural properties of frankfurters.

4. Effect of fat replacers on cholesterol and fatty acids content

High fat foods normally composed by saturated fatty acids, cholesterol and trans fatty acids have been reformulated to be healthier. The primary source of saturated fatty acids ingested by humans includes meats and their by-products that have animal fat as lipid source **(Paglarini et al., 2022).** A higher level of polyunsaturated fatty acids (PUFA) and lower level of cholesterol can increase high-density lipoprotein and reduce incidence of coronary heart disease **(Youssef and Barbut, 2009).** The reformulation of the meat products therefore represents an important to make them healthier for human consumption. Adding fat substitutes to meat product can reduce the fat content, cholesterol and enhance the distribution of fatty acids **(Ren et al., 2022). Cengiz and Gokoglu (2005)** investigated the changes in cholesterol content of sausage which processed with beef meat and containing citrus fibre (CF) and soy protein concentrate (SPC) at 2% as a fat replacers, wherever the fat content of sausage was reduced from 20 to 10 and 5%. They obtained that the cholesterol content significantly decreased with decreasing fat level. Also, addition of CF and SPC significantly ($P<0.01$) decreased the cholesterol values. There was no difference between sausage treated with CF and those treated with SPC for cholesterol content. The gelled emulsion prepared with commercial canola and olive oils were an effective ingredients as partial or total pork back fat replacers in beef burgers, significantly improving the fatty acid profile, the 50% replacement of fat by canola oil gelled emulsion as excellent strategy to reduce the total saturated fat content in low fat beef burgers **(Dias et al., 2022).** The soy proteins and oat as fat replacers considered excellent sources of soluble fiber that have been effective in reducing cholesterol. In addition, oat is particular interest as an ingredient as they may help to control obesity, hypertension, diabetes and heart disease **(Yang et al., 2007). Candogan and Kolsarici (2003)** evaluated the effect of carrageenan at 0.3, 0.5 or 0.7% with a pectin gel at 20% on cholesterol content of low fat beef frankfurters which containing 3% fat in comparison to a high fat control (HFC) 17% fat. They found that HFC had the highest cholesterol content (93.25mg/100g), and reduction of fat from 17.07% to less than 3.0% resulted in 50-56% lower cholesterol in low –fat frankfurters. The incorporation of vegetable oils (IVOs) prepared from palm, cottonseed and olive oil in frankfurters improved the nutritive value of product due to altering the fatty acid composition **(Vural et al. 2004).**

There is concern about the safety of trans fatty acids in the human diet, because of possible relationship between trans fatty acids intake and cardiovascular disease. Intake of trans fatty acids has been shown increase the concentration of low-density lipoproteins in the blood and to decrease the concentration of high-density lipoproteins **(Dias et al., 2022). Yilmaz (2004)** study the effect of rye bran addition on the fatty acid composition of low fat meatballs. He found that the highest amount of total trans fatty acids was found in the control samples and the lowest in the 15% and 20% added rye bran meatball samples. The meat balls containing oat bran had lowest concentration of total fat and total trans fatty acids than control samples **(Yilmaz et al., 2003).** Since the fatty acid composition and proportion significantly impact human health, the (PUFA) to saturated fatty acids (SFA) ratio should be between 0.4 and 1.0 **(Ren et al., 2022).** The ratio of PUFA to SFA increased significantly from 0.51 to 1.96 for the control beef patties and emulsion gels prepared with chia mucilage and olive oil in beef patties($p<0.05$) respectively **(Liu et al., 2022).**

5-Effect of fat replacers on lipid oxidation

Primary products of lipid oxidation are hydroperoxides which are turned to peroxides, therefore into seemed to be reasonable to determine the concentration of peroxides in meat products to study the extent of oxidation **(Abd El-Alim et al., 1999; Ren et al., 2022).** Cholesterol is relatively stable compound, but it can be oxidized under bad conditions. The oxidation of cholesterol in muscle foods can be influenced by many factors such as processing temperature, storage time, packaging conditions and lipid composition **(Nam et al., 2001).** Also, unsaturated fat are prone to oxidation, resulting in nutrient loss and a decrease in the sensory properties of the product, which can negatively impact health, requiring antioxidant protection **(Ren et al., 2022).** Previous studies obtained different results regarding specific oxidation stability. **Ferreira et al. (2022)** studied the effect of replacing the pork fat (4%) with the same amount of hydrogel emulsion incorporating olive oil or sunflower oil in goat meat burgers. They found that the use of hydrogel emulsions did not negatively affect the quality characteristics assessed in product and improved the oxidative stability the storage of cooked burgers. The lipoids stability of fat replaced burgers given that high level of polyunsaturation of vegetable oil fatty acid could be a factor to making the fat replaced burgers highly susceptible to oxidation, thus causing alterations in sensory properties. On the other hand, vegetal oils usually contain higher antioxidant capacity than animal fats, which contribute to preventing lipid oxidation. The antioxidant capacity in oat flour as fat replacer is similar to ascorbic acid , tocopherol or uric acid , and the peroxide values decreased as oatmeal addition increased. This might be due to the effect of oatmeal addition as a source of antioxidant **(Holguin-Acuna et al., 2008).**

Liu et al., (2022) prepared emulsion gels with chia and olive oil as fat replacers in beef patties. Their results showed that the reformulated patties obtained higher lipid stability than control samples, increasing the polyunsaturated fatty acids content of the emulsion gel might enhance the lipid oxidation during the cooking process. Hence, the presence of olive oil itself should favour lipid oxidation due to the content of monounsaturated fatty acids and hence higher level of lipid unsaturation.

6. Effect of fat replacers on sensory properties

The most important quality aspects of meat products are tenderness, juiciness, flavour, colour and other characteristics, which are also the most variable quality traits. The sensory panels were convened to assess the effect of the addition of fat replacer on the sensory properties of low-fat meat product. Based on the results of panel tests, Italians sausage containing Hydrated oat were found to have significantly higher tenderness and juiciness than the control sample, which could be attributed to increased moisture retention of the product during cooking**(Kerr et al., 2005).** Also, **Piňero et al., (2008)** found that the oat's soluble fibre aided in water retention, produced juicier low-fat beef patties. **Garcia et al. (2002)** investigated the effect of the addition of dietary fibres as cereal fibre (wheat, oat bran) and fruit fibres (apple, peach, and orange) on sensory properties of reduced fat dry fermented sausage which made from lean beef. The results showed that reduced fat sausages fortified with dietary fibre can be obtained with an acceptable sensory profile. The tenderness and juiciness in the sausage products were improved by the addition of hydrated oatmeal **(Yang et al. 2007).** Bacterial cellulose as a fat replacer in emulsified meat products proved to be a potential fat replacer, as it maintained the same technologycal and sensory properties found in products with original fat content (**Oliveira et al., 2022). Vural et al., (2004)** obtained that the incorporation of vegetable oils which prepared from palm, cotton seed and olive oil at 6% and 10% and sugar beet fiber at 1% did not lead to a significant change in appearance, texture flavor or sensory scores of beef frankfurters which replaced the beef fat (10%) by one of the inter-esterified vegetable oils for 60% and 100% compared with the control (10%).

Choi et al. (2010) observed that the low-fat meat batters without grape seed oil and rice bran fibre had the lowest values for hardness and as the grape seed oil concentration increased the hardness increased. But with reduced fat meat batter containing grape seed oil and rice bran fiber the cohesiveness, gumminess, chewiness was higher than in the control samples. The incorporation of grape seed oil and rice bran fiber with low fat meat batter successfully reduced the animal fat in the final products while improving other characteristics. **Youssef and Barbut, (2009)** studied the effect of protein level and fat / oil on sensory attributes of beef meat batters formulated with increasing protein levels (10 – 15%) and containing 25% beef fat and compared to meat batters prepared with 25% canola oil. They indicate that the hardness of cooked meat batter showed a significantly higher value when the protein level was raised, and was higher at a similar protein level. Also, product chewiness was higher in the canola oil treatment as cohesiveness and gumminess compared to the beef fat emulsion.

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