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THE IMPACT OF FRUIT FIBER ON MEAT PRODUCTS: A MINI REVIEW

Diana-Remina MANOLIU, Marius Mihai CIOBANU, Mihai Cătălin CIOBOTARU, Bianca Georgiana ANCHIDIN, Paul Corneliu BOIȘTEANU

"Ion Ionescu de la Brad" Iasi University of Life Sciences, 3 Mihail Sadoveanu Alley, 700490, Iasi, Romania

Corresponding author email: paul.boisteanu@iuls.ro

Abstract

The meat industry is making technological advancements in order to provide food that is both healthier and more sustainable. The purpose of this study is to provide an overview of the impacts that may be attributed to the incorporation of whole fruits or byproducts in a variety of forms into different meat products. The review investigated the effects that these incorporations have on physicochemical and technological features, sensory characteristics, and the potential to improve shelf life. The incorporation of fruit fiber into meat products led to an increase in cooking yield, emulsion stability, capacity to bind water and fat. However, it also resulted in a reduction in shrinkage, cooking losses and pH, with variations depending on the concentration, type, initial pH, and storage period. The addition of dietary fiber led to an increase in hardness and chewiness, despite the fact that it enhanced the water-holding capacity and reduced the cooking loss. It was found that the effect on the instrumental color characteristics and color sensory perception differed depending on the source of the addition and its color.

Key words*: byproducts, fruit fiber, meat products, quality parameters.*

INTRODUCTION

In general, dietary fiber includes carbohydrates that the human body is incapable of digesting in the small intestine, but undergo fermentation in the large intestine. Although there exist multiple methods for categorizing this group of components, the most common system of classification involves determining its solubility in water. Soluble fiber undergoes fermentation more readily than insoluble fiber (Bajcic et al., 2019). The most representative exemples are: structural polysaccharides including cellulose, hemicellulose, and pectin; oligosaccharides including inulin and oligofructose; lignin found in the cell wall of plants; lignin derivatives including wax and suberin; seaweed polysaccharides such as carrageenan, agar, and alginate, as well as gum agents devoid of structural constituents like gum arabic and guar gum (Arslan et al., 2021; Mishra et al., 2023).

Given their content in vital nutrients including vitamins, minerals, and fibers, fruits and vegetables influence positively the health of individuals, those components serving diverse physiological functions within the body and provide advantages to human organism (Cassiano et al., 2024). However, following sanitation, fruit and vegetable processing is one of the most substantial industries contributing to environmental waste. Fruits and vegetable processing wastes comprise approximately 30% to 50% of the overall fresh product. These wastes, including peel and seeds, contain significant amounts of high-value materials that are capable of being repurposed. Consequently, they possess considerable economic value. The utilization of these by-products in the manufacturing of dietary supplements or food additives that are nutritionally significant has garnered growing interest; consequently, their economic viability is enhanced by their recovery (Sakr et al., 2023).

Meat and meat products are versatile and nutritionally dense due to the presence of bioactive compounds, fat-soluble vitamins, minerals, trace elements, and proteins with high biological value. Meat, despite its considerable nutritional value, is notably lacking in dietary fiber (Das et al., 2020) and is a significant source of cholesterol and saturated fatty acids, both of which have been associated with health complications (Arslan et al., 2021; Younis et al., 2022).

Nowadays, consumers become more aware of the correlation that exists between nutrition and health. This highlights the need to design functional products by improving their quality with dietary fibers, essential oils, or various plant extracts (Anchidin et al., 2023; Lungu et al., 2023). Due to the health benefits, technological enhancements and the improvement on shelf life associated with the incorporation of dietary fiber into meat and meat products, this has become a topic of increased interest among scientists (Dragomir et al., 2023). Ratulangi et al. (2022) demonstrated that the addition of purple sweet potato flour (*Ipomoea batatas* L.) to chicken nuggets (at levels of 10, 20, 30, and 40 grams) resulted in a decrease in water content and an increase in fat, protein, and dietary fiber content. Additionally, it improved the antioxidant activity of the nuggets.

Therefore, besides their economic value and nutritional benefits, dietary fiber sourced from vegetable sources also have a structural benefit on the meat products, improving cooking parameters, such as cooking loss, cooking yield, diameter reduction (Boișteanu et al., 2023), water holding capacity (Sakr et al., 2023), expressible water (Al et al., 2024; Barbut, 2023).

Dietary fiber is a vital component of a balanced diet, promoting digestive health, weight control, and reducing the risk of chronic illnesses (Arslan et al., 2021). However, consumption often falls below recommended amounts due to widespread consumption of refined and processed foods. Understanding consumer preferences regarding dietary fiber content is crucial for market segmentation in the food industry.

Lungu et al. (2023) reported in a study evaluating the incorporation of different vegetable derivatives (such as extracts or powders from walnut leaves and cherry stems, pumpkin seed protein, chickpea protein isolate, mushrooms) in meat products that these supplements have a positive effect on overall quality and that the sensory attributes are accepted by consumers, if not even perceived as improved.

Therefore, this review aims to investigate the effect of different dietary fibers found in fruits and their impact on the qualitative attributes of meat and meat products, including their nutritional addition, technological and physical quality, effect on shelf life and sensory perception.

MATERIALS AND METHODS

The present literature review includes studies summarizing the outcomes of incorporation of fruit fiber in different forms (powder, paste, flour, pomace) into meat products (for exemple, burgers, sausages, nuggets, meat patties, meatballs). The main variables followed to highlight the effects of the additives applied to the products were the physico-chemical and technological properties, the potential to extend shelf life (through the antioxidant properties of the added fibre) and sensory properties.

The literature search was performed utilizing Web of Science, ResearchGate and Google Scholar as search platforms. The inclusion criteria for this study extended to English-language articles and had full-text accessibility. Research examining the impact of fruit fiber on the supplementation in animal feed was similarly disregarded. The eligibility criteria included only research that examined the use of whole fruit, fruit byproducts or fruit fiber in meat products. For the search, the subsequent word combinations were implemented: fruit fiber in meat products, fruit byproducts in meat products, meat products enriched with fruit fiber.

A total of 68 publications were returned by the initial search; the results were imported via Mendelay Desktop (by Elsevier Limited, version 1.19.8) and duplicates were removed. After removing duplicate articles from the databases, 61 studies remained. Following that, abstracts from the remaining articles were assessed in order to identify those that were pertinent to the subject of the study. After conducting a comprehensive examination of the complete papers to verify adherence to the inclusion criteria, 30 articles remained. Further analysis was conducted on the reference lists of the chosen papers in order to identify publications that might have been pertinent. After conducting an exhaustive evaluation of complete texts, a total of 23 publications were deemed suitable for inclusion in this review.

RESULTS AND DISCUSSIONS

Impact of adding dietary fiber on the physical and chemical characteristics of meat products

The incorporation of fiber into meat products has altered their overall composition, resulting in the emergence of novel fiber sources and presenting promising opportunities for their utilization in many industries. Table 1 shows the effect of fruit fiber on technological and nutritional quality of different meat products.

The incorporation of blanched date pulp in camel meat burgers had a significant impact on the moisture, protein, and fiber levels of the cooked samples. In contrast, the ash and fat content were not affected by the date pulp addition. The moisture content of the raw burgers decreased from 58.32% in the 0% pulp formula to 55.82% in the 15% date pulp formula. Additionally, there was a considerable rise in the fiber levels and a decrease in the protein content. Moreover, the inclusion of date pulp resulted in a substantial rise in the levels of K, Ca, Zn and Mg, while simultaneously reducing the levels of Fe and Cu (Abd El-Hady et al., 2022). A similar increase in mineral content (calcium, magnesium, potassium, and iron), described by Kęska et al. (2023), was produced by the addition of lyophilized dragon fruit in baked pork meat. The observed rise in mineral content can be attributed to the high concentration of vital nutrients present in dates and lyophilized dragon fruit pulp, as they serve as a valuable reservoir of iron, cobalt, zinc, and calcium, while also exhibiting higher-than-average levels of potassium and magnesium (Ayad et al., 2020; Kęska et al., 2023). Despite the decrease in water content in the raw burgers, the cooking characteristics showed an improvement, namely the shrinkage and cooking loss of the patties decreased from 26.67% and 36.98% (in control samples) to 9.17%, respective 31.76% (in the 15% formulation).

The research of Sánchez-Zapata et al. (2011) showed that the addition of date paste in bologna sausages resulted in an increase in moisture, ash, and total dietary fiber content, while causing a decrease in protein and fat content. However, these changes were only statistically significant when the date paste was introduced at a concentration exceeding 5%. The only parameter that exhibited significant changes across all treatments was the total dietary fiber content, the increase being directly proportional to the concentration of added date paste. The results of the proximate analysis revealed that bolognas with 10% and 15% date paste exhibited the maximum moisture content. This observation may be attributed to the water content and water-holding ability of the date paste.

Similar results were reported by Besbes et al. (2010), who found a decrease in dry matter (wt.%) in beef burgers formulated with 1.5% date fiber concentrate. The authors explain the increase of water content by the fact that adding a higher percentage of date fiber concentrate, the formulation needed a higher quantity of water.

In a particular study, the inclusion of dried apple pomace in chicken sausages resulted in a decrease in moisture and protein content, and an increase in crude fiber, while the fat content did not differ significantly (Yadav et al., 2016). Incorporating dry apple pomace (DAP) into sausages resulted in notable improvements in cooking yield and emulsion stability across all treatments, with a significant enhancement observed at the 6% level of fiber incorporation. These improvements can be attributed to the fiber's capacity to retain water and fat within the treated sausages. Interestingly, there was a significant decrease in pH values noted. This decrease in pH was attributed to the inherently acidic nature of DAP, which has a pH of 4.80.

Ahmad et al. (2021) reported that apple peel powder determined a decrease in pH values of buffalo meat fillets observed within the first 7 days of storage, followed by a significant increase thereafter. The initial decrease in pH can be ascribed to microbial activity that converts accessible carbohydrates into organic acids, causing this shift. Following this, on the seventh day, a significant rise in pH is observed, potentially attributed to a microbial transition towards protein utilization as a food source; as a result, the product contains a greater concentration of alkaline protein-based degradation metabolites.

The overall findings suggest that the inclusion of DAP in sausages not only enhances their physical properties but also influences their acidity levels, potentially affecting flavor and texture profiles (Yadav et al., 2016; Ahmad et al., 2021).

The moisture of chicken meat nuggets decreased with the addition of orange albedo, due to the low water content of orange albedo. This aligns with previous studies indicating lower moisture content in beef burgers enriched with orange albedo flour (Silva et al., 2020). Protein and ash content do not significantly differ, but slightly increase with fiber addition from citrus albedo, while the fiber content increase significantly. The highest fiber content was found in the meat products containing the higher citrus albedo powder (Fernández-Ginés et al., 2004; Ammar, 2017; Silva et al., 2020).

Table 1. Effect of fruit fiber on technological an nutritional quality

Meat product	Type of fiber added	Dosage used	Technological effect	Nutritional modifications	Reference
Camel Meat Burger	Date fruit pulp	2.5%, 5%, 7.5%, 10%, and 15%	↓ Shrinkage; Cooking loss ↑ Cooking yield	↓ Moisture and protein ↑ Total carbohydrate; fiber; K and Ca levels NSD Fat	Abd El-Hady et al., 2022
Bologna sausages	Date paste	5%, 10% and 15%	ND	↑ Moisture; ash; total fiber content ↓ Protein and fat content	Sánchez-Zapata et al., 2011
Chicken sausages	Dried apple pomace (DAP)	3, 6 and 9%	↑ Cooking yield, emulsion stability	↓ Moisture, protein ↑ Crude fiber NSD Fat	Yadav et al., 2016
Chicken meat nuggets	Orange albedo powder	5% and 10%	↓ pH; frying shrinkage ↑ Frying yield, moisture retention	↓ Moisture ↑ Protein, fat, ash and fibre content	Ammar, 2017
Beef burgers	Orange albedo flour	2.2%; 4.3%; 6.5% and 8.7%	↑ Shrinkage ↓ Cooking yield, WHC	↓ Moisture, fat ↑ Protein, fiber, ash content	Silva et al., 2020
Emulsified Alpaca Sausages	Red dragon fruit peel powder	3.29%, 6.57%, and 9.86%	↓ Cooking yield ↑ Frying loss	↑ Moisture, total fiber ↓ Total lipids and protein contents	Corimayhua-Silva et al., 2024
Spam-like products	Passion fruit albedo flour	2.5%, 5%, 7.5% and 10%	↓ Cooking losses, water exudations ↑ Fat exuded	↓ Moisture, protein ↑ Carbohydrates and TDF	dos Santos et al., 2021
Chicken meat patties	Pomegranate peel (PPP) and bagasse powder (PBP)	0.01% and 2%	↑ Water holding capacity; emulsion stability, cooking yield	↓ Moisture, protein (in the PPP addition) ↑ Fat, ash, crude fibre	Sharma & Yadav, 2020
Pork meatballs	Kiwi fruit pomace fiber	0.5%, 1%, 3%, 5% and 7%	↑ Cooking yield, emulsion stability and water / fat binding abilities	↑ Moisture, carbohydrate ↓ Fat NSD Protein	Zhao et al., 2021

↑ - the addition of fiber increased the value of the parameter; ↓ - the addition of fiber decreased the value of the parameter; NSD - no significant difference; ND - not determined.

In one study the moisture and fat content of spam-like products was not substantially impacted by the concentration of passion fruit albedo flour (PFF). Conversely, the protein and total carbohydrate contents exhibited variability in response to the quantity of PFF introduced, with a tendency for carbohydrate content to increase and protein content to decrease. Physicochemical characteristics of the spam-like products such as weight loss on cooking, water and fat exuded registered a decrease with the increase of PFF added (dos Santos et al., 2021). Similar results were described by López-Vargas et al. (2014), where the addition of passion fruit albedo (PFA) in pork burgers induced a decrease in moisture and protein content, while improving the cooking characteristics in terms of yield, fat and moisture retention. Those findings are related to the fibers characteristics that function as emulsion-stabilizing agents, thereby contributing to the retention of water and lipids in the food matrix by increasing water retention via their jellifying capacity (dos Santos et al., 2021).

The impact of dietary fiber inclusion on the color, texture, and sensory attributes of meat products

Modern consumer perception encompasses both pre-purchase and post-purchase value of a product, leading to the concept of loyalty as a general attitude towards a product. In general, loyalty is demonstrated through three stages: conative intention, attitude, and belief. As each phase is completed, loyalty and commitment improve. A complete perceptual experience is formed by summing all of the component sensations caused by various factors such as organoleptic sensations, affective sensations and perceptions, or sensations associated with environmental conditions, all of which constantly interact to produce the final acceptability (Ciobanu et al., 2023). Customer acceptability of meat products is determined by several critical sensory attributes, namely aroma, flavor, color, appearance, tenderness, and juiciness.

The incorporation of kiwi fruit pomace fiber into pork meatballs (increasing levels, from 0.5% up to 7%) resulted in enhanced tenderness while leaving the meat juiciness unaffected, but only with a maximum level of 3% kiwi fruit pomace fiber. At higher levels of kiwi fruit pomace fiber (5 and 7%) a decline in appearance, flavor and texture scores was registered, while the instrumental determined hardness increased significantly. The overall acceptability decreased, the closest to the control sample in sensory perception being the formulation with 3% addition (Zhao et al., 2021).

Adding lemon albedo to bologna sausages did impart the acidic flavor, the perception increasing for doses above 5% of albedo. Conversely, the perceptual impact of the color red and also the instrumental reading of color was negatively affected through the incurporation of fresh lemon albedo. However, samples with albedo also showed higher lightness values and were perceived as shinier (Fernández-Ginés et al., 2004). The sensory acceptance of beef burgers with a low addition of orange albedo flour (2.2% and 4.3%) did not differ from the control. However, the scores for color, appearance, flavor, texture, and overall liking decreased with the addition of 6.5% and 8.7% orange albedo flour. This may have led to the perception of fruity flavors (Silva et al., 2020).

The incorporation of fiber extracted from pumpkin into frankfurter sausages at a concentration of 2% yielded final products of exceptional quality taking into account that the addition of pumpkin fiber was made with the purpose of reducing the fat content. The color, flavor, tenderness, juiciness, and overall acceptability scores of frankfurters showed a tendency to decrease by reducing added pork fat levels without adding the pumpkin fiber, while treatments with pumpkin fiber added received higher sensory scores (Kim et al., 2016).

The extent to which fiber is incorporated into the meat product can alter its ultimate properties. In this sense, the sensorial perception of chicken meat balls enriched with grape pomace powder and pomegranate pomace powder (GPP/PPP; 1%/0.5%; 2%/1%; 3%/1.5%; 4%/2%) decreased in all samples compared to the control group, the 1% / 0.5% formulation was evaluated the closest to the control sample in terms of appearance and color, texture, tenderness and overall acceptability (Santhi et al., 2020). Mango peel pectin (MPP) incorporated in dried Chinese sausages at 5%, 10%, and 15% levels indicated that as the concentration of MPP applied increases so does the pigmentation and yellowness of the sausage in all formulated products, as well as the intensity of the color, while the lightness value decreases. The findings revealed that the hardness of the formulated samples did not vary substantially. The control sample achieved the greatest hardness value of 15.87 N, that decreased slightly with the addition applied. Nevertheless, interventions incorporating pectin fibers resulted in reduced levels of springiness, cohesiveness, gumminess, and chewiness. The inclusion of MPP resulted in sausages with a noticeably softer consistency. This may be related to the gel strength of the quantity of pectin compressed (Wongkaew et al., 2020). The variations in hardness profiles observed may be attributed to the fat and MPP mixture's capacity to bond and retain water.

The impact of dietary fiber addition on the shelf-life of meat products

Preserving the quality and retail stability of a meat product throughout its storage period is critical. Diverse effects of incorporating various types of fiber sources into meat products have been observed to affect their preservation quality. A frequently employed method for assessing oxidative stress in foods is the analysis of TBA (thiobarbituric acid) metabolites generated during preparation. The method measures the MDA (a substance that undergoes a reaction with thiobarbituric acid) content of meat products, serving as an indicator of their quality (Mazur et al., 2021).

Table 2. Effect of fruit fiber on oxidative stability, sensorial and physical quality

Meat product	Type of fiber added	Dosage used	Effect on oxidative stability	Sensorial modifications	Physical quality	Reference
Homogenized meat products	Guelder rose (*Viburnum opulus*)	0.05%, 0.1%, 0.15%	↑ oxidative stability microbiological quality ↓ TBARS levels	↑ Sensory acceptance in overall appearance and color ↓ acceptability of taste and smell by increasing the addition of GRFP	↓ pH, L*, a* (on a 14 days storage period)	Mazur et al., 2021
Chicken Meat Nuggets	Drumstick (*Moringa oleifera*) flower	1% and 2%	↑ Total phenolic content (mg GAE/g), oxidative stability ↓ TBARS values (mg MDA/kg), microbial count (log cfu/g) on a 20 days storage time	↓ Sensory attributes (especially after 15 days of storage) The control group received a lower taste score and a rancid odour on day 15, which may have reduced taste and acceptability scores	↑ L*, b* ↓ a*, pH, hardness (N/cm^2), gumminess, chewiness	Madane et al., 2019
Pork burgers	Passion fruit albedo (PFA)	2.5% and 5%	↓ Lipid oxidation (raw and cooked sample)	↓ Color intensity; fatness perception ↑ Flavor perception; meaty flavor, taste intensity score	↑ L* (raw burgers), a*, b* (raw burgers), hardness, chewiness ↓ L* (cooked burgers)	López-Vargas et al., 2014
Chicken meat nuggets	Orange albedo powder	5% and 10%	*NSD* TBARS values on day 0 ↓ TBARS values for a 20 days storage time ↑ control in lipid oxidation	↑ Color and appearance perception ↓ Flavor, texture and juiciness perception; overall acceptability	↑ a*, b*, Hardness, Chewiness, Gumminess ↓ L*, Cohesiveness, *NSD:* Springiness	Yadav et al., 2016
Pork meatballs	Kiwi fruit pomace fiber (KWIDF)	0.5%, 1%, 3%, 5% and 7%	↓ TBARS values (indicating that the oxidation stability of low-fat meatballs could be improved by the addition of KWIDF)	↓ Appearance scores, flavor and texture; overall acceptability ↑ Juiciness scores (in the 3% KWIDF)	↑ a* and b*, hardness, gumminess, chewiness (by adding 5% and 7%). ↓ pH, L*, hardness, gumminess and chewiness (by adding 0.5%, 1%, 3%)	Zhao et al., 2021

↑ - the addition of fiber increased the value of the parameter; ↓ - the addition of fiber decreased the value of the parameter; NSD - no significant difference

The inclusion of 1% pomegranate seed and peel extract in chicken patties determined a rise in TBA concentrations during storage, the control sample C demonstrated the most substantial increase, culminating in a maximal value of 1.221 mg MA/kg after a duration of 12 days in refrigeration. Samples added with pomegranate seed and peel extract exhibited marginal increases in MA content (0.637 and 0.632 mg/kg, respectively). This observation illustrates the effect that these extracts have on the oxidative stability of the product, possible cause of the decreased TBA concentrations can be the phenolic compounds and natural antioxidant components in pomegranate seeds and skins (Al et al., 2024). Similar results were reported by Sharma & Yadav (2020) for chicken meat patties enriched with pomegranate peel powder (PPP, 2%) and pomegranate aril bagasse powder (PABP, 4%). In this study, TBA values substantially increased for both treated and control patties during refrigeration storage. However, during the storage period, the TBA values of chicken patties treated with PPP and PABP remained substantially lower than those of the control group. The increase in TBA value was from 0.56 mg malonaldehyde/kg for the control sample on day 0 to 1.95 mg MA/kg on day 16 of storage; while in the samples with added PPP and PABP the TBA value increased from 0.24 mg MA/kg and 0.30 mg MA/kg respectively to 0.81 mg MA/kg and 0.84 mg MA/kg, respectively on day 16 of storage.

Kęska et al. (2023) reported across the entire duration of storage of 21 days, products enriched with lyophilized dragon fruit pulp exhibited, on average, greater TBARS values. An anomaly was observed in the variant containing the least amount of lyophilizate, specifically 0.5%. In proportion to the dose administered, the extent of the difference in TBARS levels is directly notable. Specifically, during the entire storage period, the formulation with 4% variant demonstrated a greater quantity of secondary fat oxidation products in comparison to the control. The mean values of mg MDA/kg as determined for homogenized meat products enriched with freeze–dried guelder rose fruit powder (GRFP), during the initial experimental phase (post-production), exhibited notable distinctions between control sample and prepared formulations with 0.05, 0.1, 0.15 g/100 g of GRFP. The formulation lacking GRFP contained a greater quantity of MDA compared to the groups supplemented with GRFP. Furthermore, it was observed that sample with the greatest concentration of GRFP (0.15 g/ 100 g) had the least quantity of MDA, and the greatest resistance to lipid peroxidation (Mazur et al., 2021). During the fourteen-day storage period at 4°C, elevated MDA concentrations were observed in all samples relative to those determined on day zero; this was attributed to lipid peroxidation. Samples containing 0.05 and 0.1 g/100 g of GRFP exhibited a comparable antioxidative effect, as evidenced by the average TBARS values of the experimental samples.

CONCLUSIONS

The incorporation of dietary fiber into meat products has shown diverse effects on their physical, chemical, sensory, and shelf-life attributes. Various fiber sources, such as blanched date pulp, lyophilized dragon fruit, and dried apple pomace, have demonstrated significant alterations in moisture, protein, fiber, and mineral content, presenting novel opportunities for enhancing product quality and nutritional value. Additionally, fiber addition has influenced cooking characteristics, such as shrinkage and cooking loss, while also impacting pH levels. Sensory evaluations have revealed changes in aroma, flavor, color, texture, and overall acceptability, depending on the type and concentration of fiber incorporated. Furthermore, fiber inclusion has shown potential in improving oxidative stability and extending shelf life by reducing lipid peroxidation. However, careful consideration of fiber type, concentration, and processing methods is essential to optimize product quality and consumer acceptance. Overall, the findings underscore the multifaceted benefits and challenges associated with incorporating dietary fiber into meat products, highlighting the need for further research to harness the full potential of this approach in the food industry.

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