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The effect of the addition of pineapple residue (*Ananas comosus L.*) on texture, physicochemical properties, and sensory acceptability of the plant-based minced meatball

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Dietary fiber; Pineapple residue; Plant-based meatball; Texture; Sensory acceptability.

This study aims to develop plant-based meat alternatives with unique textures by adding pineapple residue at four different ratios (0, 5, 10, 15, and 20% w/w). The developed products' textures, sensory characteristics, nutritional values, and consumer acceptance were all assessed. The results showed that an increase in the pineapple residue content caused lightness (L*), redness (a*), as well as yellowness (b*) to increase. The textural properties of the plant-based minced meatballs in this study were relatively lower than those of beef minced meatballs. The adhesiveness, springiness, and chewiness of the plant-based minced meatballs showed a declining tendency with an increase in the amount of fiber in the formulation, especially at 20% pineapple residue. This would be beneficial for consumers' consumption. This study clearly showed that the addition of pineapple residue at 5–20% w/w provided an overall liking score of more than 6.0, which was considered acceptable. Therefore, the combination of mushroom and pineapple residues could influence the color, texture, and liking scores, especially at 20%. Producing plant-based meat products from pineapple by-products is an efficient way to improve dietary fiber in diets, lower global warming, and increase future food security, while also increasing nutritional values.

1. Introduction

Ground meat products such as meatballs, burgers, and meat patties are highly accepted and consumed worldwide (Turgut et al., 2017), mainly due to the increase in the number of fast foods worldwide and their convenience as well as low prices (Selani et al., 2016). However, ground meat products have some drawbacks such as the quantity (20–30%) (Jiménez-Colmenero, 2000) and quality of their fat as well as the cholesterol content, which are associated with the occurrence of some chronic diseases (Fernández-Ginés et al., 2005).

Oostindjer et al (2014) reported that red and processed meat contained a high content of fat, especially saturated fat. Red and processed meat consumption of more than 500 g per week increases the risk of diseases such as cancers, obesity, and cardiovascular disorders. Additionally, with an increase in global population and rapid economic development, the last two decades have seen a 58% growth in the global demand for meat (Whitnall and Pitts, 2019) and it is predicted that this market will expand by 15% by 2027 (OECD/FAO, 2018). However, in recent years, concerns about the negative effects of meat consumption on human health and the inefficiency of meat production compared to crop harvesting have been widely discussed (Hygreeva et al., 2014). Hence, growing health concerns and consumer demand has led to the development of healthier food varieties. Among all commercial meat alternatives, plant-based meat has the most potential to become a mainstream product. Due to the recent development of various plant-based meat brands such as Beyond Meat™, Impossible Food™, and Light Life ™, public media has reported that 2019 has been the year of plant-based burgers (He et al., 2020).

With consumers believing these products promote good health while also being environmentally friendly, interest in plant-based meats is growing rapidly. A life cycle analysis commissioned by the industry revealed that the manufacture of plant-based meat products generated 90% less greenhouse gas emissions (GHGe) and used 46% less energy and 93% less land than the manufacture of beef-based meat products (Estell et al., 2021). Plant-based ingredients such as wheat gluten, soy protein, mushrooms, rice, and legumes are processed in combination with flavoring additives to produce a final product that tastes like meat (Kyriakopoulou et al., 2019). Therefore, a challenge for producing a plant-based meatball with satisfactory meat-like characteristics is to develop plant-based meats from mushrooms, fibers, and other ingredients.

Mushrooms are a great option for plant-based meat production because they are rich in sulfur-containing amino acids, which can help to achieve a meaty flavor. In addition, mushrooms are rich in biological activity components, which can provide many health benefits including an antitumor property (He et al., 2020). The use of dietary fibers as a functional ingredient is related to their interesting properties that can positively affect meat products (Selani et al., 2016). Fibers have been effectively applied to improve the water-holding and swelling capacities of products, along with boosting yield and modifying texture and viscosity (Elleuch et al., 2011). In addition, it is acknowledged that insoluble dietary fibers act as a bulking agent, normalizing intestinal motility, and preventing constipation; while soluble fibers are associated with decreasing the intestinal absorption of cholesterol and glucose (Silveira et al., 2003).

Dietary fibers are mainly obtained from cereals. However, fruits and vegetable by-products still have high dietary fiber content (Mateos-Aparicio and Matias, 2019). Pineapple is a widely consumed tropical fruit and part of its production is intended for the manufacture of juices, fruit salads, canned fruits, and jams.

The manufacture of these products generated residues which are mainly composed of peel and core and account for about 25–35% of the fruit. According to a previous study, pineapple by-products presented DF as its major component (75.8%) (Selani et al., 2016). Moreover, pineapple residue is a potential cost-effective source of nutraceuticals and functional foods as it is rich in phytochemicals, and that have healing properties on humans such as anti-hypertension, anti-cancer, anti-cardiovascular, and other degenerative diseases (Gupta et al., 2017). Aparecida Damasceno et al. (2016) and Selani et al (2016) reported pineapple residue is processed into healthy food such as cereal bars, and beef burgers. However, the application of pineapple residue in food is very limited data.

Therefore, this study aims to evaluate the effect of the addition of pineapple residue (PR, pineapple by-product extracts) on the textures, sensory characteristics, and nutritional values of the plant-based minced meatball which could contribute towards healthy food and a sustainable environment

2. Materials and Methods

2.1 Preparation of raw materials

Pineapple residue (*Ananas comosus L.*) was obtained from a pineapple processing factory (V & K Pineapple Canning Co., Ltd, Ratchaburi, Thailand). At the factory, the pineapple was sanitized with 200 ppm of sodium hypochlorite, rinsed with water, and then sent through the pulp extractor, where the by-product was collected. The material was kept frozen until being transported. Samples were ground using a knife mill (Marconi, Piracicaba, SP, Brazil), passed through a 40-mesh sieve (diameter 420 μm), and stored at -18°C. Before processing plant-based meatballs, pineapple residue underwent a thermal blanching treatment at 100°C for 2 h to inactive the bromelain (Selani et al., 2016). Beef meat and king oyster mushroom were purchased from a supermarket in Bangkok. The raw materials were ground using a knife mill and stored at -18°C.

2.2 Plant-based meatball manufacture

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The plant-based meatballs (PBM) were produced following Yuliarti et al. (2021) formula, which was used to produce plant-based nuggets. Each composite ratio contained ice water(~4°C) 57%, 18% potato starch, 3.5% vegetable oil, 0.2% calcium chloride, 0.3% salt, 2.5% baking powder, and 1.5% MC in order to make 100 g of ground mushroom. All ingredients were homogenized in a food processor for 3 min at low speed; deionized (DI) water was used throughout the study. This step was carried out to fully hydrate the sample. Pineapple residue at four different ratios (0, 5, 10, 15, and 20%) was added to the samples. The meatball from minced beef was served as a control. The ground raw materials in each group were emulsified at 0°C–4°C for 3 h and then manually made into meatballs with a diameter of 2.5 cm-diameter and a weight of 20 g. These meatballs were pan-fried in canola oil (180°C, 3 min) on a tilting frying pan until they reached a core temperature of 75°C. After cooking, the meatballs were placed on a paper towel for 10 min to remove excess oil on their surface. Before further analysis, all meatballs were naturally cooled at room temperature (25°C) (Zhang et al., 2020).

2.3 Physical properties

2.3.1 Color

The color of the meatballs was measured using a Hunter Lab apparatus (Hunter Lab, UltraScan PRO; USA), which measures the parameters: lightness (L*), red-green (a*), and yellow-blue (b*) (Selani et al., 2016). The measurements were taken of the inside and outside on the surface of each of the samples. The average values of 10 measurements were recorded

2.3.2 Texture profile analysis (TPA)

TPA was performed following a method of Kehlet et al. (2017) with slight modifications. The texture analyzer was equipped with a 100 kg load cell and a 100 mm cylindrical probe (P/100). Samples were measured at room temperature; pre-test speeds, test speeds, and post-test speeds of 1.0, 5.0, and 5.0 mm/s, respectively; 75% strain; and trigger force of 5.0 g. The hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness of meatballs were determined.

2.3.3 Sensory evaluation

Untrained panelists (n = 50) were recruited from Suan Sunandha Rajabhat University, Bangkok, Thailand. The inclusion criteria were panelists who were between 18 and 60 years old, were regular minced meatball consumers, and had no history of food allergy. Panelists with asthma or an allergy were excluded. Each panelist received a sample served in a cup coded with a 3-digit random number to avoid bias. Panelists were provided with drinking water to clean their mouths between consecutive tastings. They were instructed to first visually evaluate the acceptability of product appearance and color and then to bite and swallow each sample before scoring it for odor, taste, firmness, and overall liking using a 9-point hedonic scale according to Meilgaard et al. (1999).

2.3.4 Analysis of nutrition values

The nutritional values of the most appropriate developed plant-based minced meatball product were evaluated in the energy, total fat, protein (N x 6.25), carbohydrate, dietary fiber, and sodium per 100 g, compared to the commercial beef minced meatball and plant-based meatball products in triplicate according to the Association of Official Analytical Chemists International (2019).

2.3.5 Statistical analysis

The data were analyzed using analysis of variance facilitated by the IBM SPSS® version 23 software (IBM SPSS Inc.; USA). Duncan's multiple range test was used to determine multiple comparisons of mean values with a statistically significant difference established at $p < 0.05$.

3. Results and discussion

3.1 Physical properties

3.1.1 Color

The color values (CIE L*, a*, b*) of different plant-based minced meatballs made from mushroom and pineapple residues are presented in Table 1. For both inside and outside meatballs, the increase in pineapple residue ratio caused the plant-based minced meatball to have L* lower than the control. This is probably due to the high dietary fiber from mushroom and pineapple residues (Selani et al., 2016). It was reported that adding dietary fiber caused a decrease in L* value, because of a combination of low light reflection, surface drying (Turgut et al., 2017), water holding capacity, and swelling capacity of fiber (Elleuch et al., 2011). These results were in accordance with a study by Yuliarti et al (2021), which reported the L* value of the plant-based nugget presented 57.02–63.73. In addition, an increasing pineapple residue caused an increase in a* (redness) and b* (yellowness) of inside plant-based minced meatballs but had no significant effect on the a* and b* values of outside plant-based minced meatballs. Furthermore, a pineapple residue ratio of 20% tended to increase the L*, a*, and b* more than the other ratios. The change in color might result from the color nature of the pineapple residue and a Maillard browning reaction of the mixture occurring during the pan-frying process. The plant-based minced meatball with high pineapple residue had a reddish-brown when compared to the beef minced meatball (control) which had a dark red-brown, as shown in Fig. 1. Studies on instrumentally measured meat color often pay great attention to a* value, which indicates redness, due to its importance on the visual appeal of meat for customers (Turgut et al., 2017).

Table 1. Color of the beef minced meatball and plant-based minced meatball with different pineapple residue ratios

Treatments	L*	a*	b*
Inside meatballs			
Control	69.57 ± 0.95^{a}	3.91 ± 0.31^{d}	17.96 ± 0.67^{c}
0% PR	44.76 ± 0.55^{c}	7.35 ± 1.02^{c}	18.97 ± 0.79^{bc}
5% PR	44.23 ± 0.69^{c}	9.74 ± 0.77^{b}	20.67 ± 0.84^{abc}
10% PR	45.94 ± 1.17^{c}	9.70 ± 0.19^{b}	20.31 ± 0.78^{abc}
15% PR	45.34 ± 0.49^{c}	9.97 ± 0.55^{b}	21.24 ± 0.41^{ab}
20% PR	60.11 ± 0.62^{b}	13.43 ± 0.35^{a}	22.45 ± 0.40^{a}
Outside meatballs			
Control	60.21 ± 0.63^{a}	8.23 ± 0.96^{ns}	27.05 ± 0.14^{ns}
0% PR	38.22 ± 0.27^{c}	10.10 ± 0.78^{ns}	18.93 ± 1.03^{ns}
5% PR	43.87 ± 0.55^{b}	10.22 ± 0.82^{ns}	22.95 ± 0.24^{ns}
10% PR	45.91 ± 0.90^{b}	11.42 ± 0.36^{ns}	23.93 ± 0.58^{ns}
15% PR	47.85 ± 0.26^{b}	11.96 ± 0.86^{ns}	25.57 ± 0.83^{ns}
20% PR	55.98 ± 0.17^{a}	12.39 ± 0.67^{ns}	29.54 ± 0.81^{ns}

PR = pineapple residue; Control = beef minced meatball

L*: lightness. a*: red to green. b*: yellow to blue

Mean ± SD with different lowercase superscripts in each column are significantly ($p < 0.05$) different; ns = not significantly ($p > 0.05$) different

Figure 1. Color of the beef minced meatball (control) and plant-based minced meatball with different pineapple residue (PR) ratios (0, 5, 10, 15, and 20%).

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3.1.2 Texture properties

Results of the texture profile analysis of the plant-based minced meatballs compared to the control are shown in Table 2. Results demonstrated a significant difference ($p < 0.05$) in adhesiveness, springiness, and chewiness, whereas the addition of pineapple residue had no significant effect on the hardness, cohesiveness, and gumminess of the treatments ($p > 0.05$). Regarding the effect of the addition of the pineapple residue (by-product extracts), it is worth noting that the plant-based minced meatballs made from mushroom and pineapple residues showed a lower texture parameter than the control. Lund et al. (2011) reported that the hardness of meat contributed to a higher intensity in protein reactions, leading to the formation of crosslinking and polymerization in proteins. It might be concluded that using plant-based ingredients to replace the meat proteins caused a decrease in the hardness of the samples compared to the control.

These results were in accordance with a study by Yuliarti et al (2021), which reported that the hardness of the plant-based nugget decreased when the amount of protein in the formulation decreased. Additionally, it was observed that adhesiveness and springiness in plant-based minced meatballs with 20% PR were significantly lower than those with 0% PR ($p < 0.05$). In general, the adhesiveness, springiness, and chewiness of the plant-based minced meatballs trend to decrease with an increasing amount of fiber in the formulation.

For example, the formulation of 20% PR which had the highest amount of fiber had the lowest adhesiveness and springiness, followed by formulations of 15% PR, 10% PR, and 5% PR. In the case of the chewiness, there was no obvious trend; however, the 20% PR in the plant-based minced meatballs formulated a decreased trend compared to the control. This reason would be advantageous for consumers' consumption due to chewiness, which was defined as the energy required to masticate the plant-based minced meatballs (Szczesniak, 2002). The textural properties of the plant-based minced meatballs in this study were relatively lower than those of beef minced meatballs. These differences may result from the meatball formulation as well as the preparation method. The incorporation of both fibers caused the meat analogs' textural characteristics to vary. A similar observation was found in the plant-based nugget (Yuliarti et al., 2021).

3.2 Sensory evaluation

The pineapple residue content was the most important affecting the plant-based minced meatball's acceptance scores on a 9-point hedonic scale. Table 3 shows that increasing pineapple residue content from 0% to 20% resulted in liking scores of all sensory attributes ranging from 5.86–6.86 (slightly likely - moderately likely). Appearance, color, taste, firmness, and overall liking scores for all pineapple residue ratios slightly decreased ($p < 0.05$) compared to the control, whereas odor scores had no significant differences ($p > 0.05$).

This could be due to the combination of mushroom and pineapple residues, providing a flavor like meat flavor. He et al. (2020) reported that mushrooms were rich in sulfur-containing amino acids, which helped to achieve a meaty flavor. The plant-based minced meatballs with 5–20% pineapple residues tended to increase the liking scores more than those with 0% pineapple residue. This outcome may be because of the physicochemical properties of fibers. Fibers have been applied to improve water holding and swelling capacities, which are useful in meat products that require hydration, increase yield, and modify texture (Elleuch et al., 2011). Besides, the overall liking scores of 5–20% pineapple residues in the plant-based minced meatball were more than 6 (slightly likely). Giménez et al. (2008) used an average value of 6 on a 9-point hedonic scale as the minimum acceptability limit for consumers liking a product. Therefore, it might be concluded that plant-based minced meatballs made from mushroom and pineapple residues could improve consumer acceptance.

3.3 Nutritional values

The nutritional values of the most appropriate developed plant-based minced meatball contained 128.82 kcal of energy, 3.68 g of protein, 2.82 g of total fat, 22.18 g of carbohydrate, 8.72 g of dietary fiber, and 293.99 mg of sodium per 100 g of sample. Calculating nutritional values in 100 g of the developed product found that this product had lower energy than commercial brands A (228.00 kcal) and B (239.32 kcal) which was related to protein and fat content. This was because the main ingredients of the product developed in this work were mushroom and pineapple residues, whereas the main ingredients of brands A and B were made from beef meat and pea proteins, respectively. According to sodium analysis, the salt content of this developed product was 293.99 mg/100 g sample, which was 1.40–2.86 times less than that of brands A and B. For dietary fiber, it was observed that the developed product had a higher dietary fiber content (8.72 g/100 g sample) than commercial brands A and B. Several reviews have recommended adding dietary fiber to meat products to enhance consumer fiber intake while also improving nutritional values (Kehlet et al., 2017).

4. Conclusion

A pineapple by-product from the manufacture of juices, fruit salads, canned fruits, and jams may be an effective and cheap solution to improve the quality of plant-based meat products. This study indicated that pineapple by-products could be used as food ingredients to produce healthier plant-based meat products. The pineapple residues were found to impact the color, texture, and liking scores. The 20% pineapple residue content was the most suitable for producing

Table 2. Texture parameters of the beef minced meatball and plant-based minced meatball with different pineapple residue ratios

Treatments	Hardness^{ns} (N)	Adhesiveness (N x sec)	Springiness (cm)	Cohesiveness^{ns}	Gumminess^{ns} (N)	Chewiness (N × cm)
Control	17014.45 ± 1070.79	-7.51 ± 14.04^{a}	0.21 ± 0.03^{a}	0.17 ± 0.03	2685.80 ± 305.35	617.41 ± 169.36^{a}
0% PR	15616.82 ± 1199.85	-11.17 ± 13.78^{a}	0.11 ± 0.01^{c}	0.14 ± 0.02	2281.65 ± 302.93	262.36 ± 60.07^{b}
5% PR	15693.45 ± 2258.72	-82.34 ± 55.31^{b}	0.12 ± 0.02^{c}	0.14 ± 0.02	2247.19 ± 341.56	268.46 ± 68.70^{b}
10% PR	14788.71 ± 604.10	-108.49 ± 26.41^{bc}	0.13 ± 0.01^{bc}	0.15 ± 0.01	2172.96 ± 126.52	276.94 ± 23.33^{b}
15% PR	15396.49 ± 2607.33	-107.73 ± 37.99^{bc}	0.13 ± 0.06^{bc}	0.15 ± 0.03	2181.69 ± 484.27	224.04 ± 62.37^{b}
20% PR	15380.93 ± 866.33	-137.94 ± 24.81^{c}	0.17 ± 0.02^{b}	0.15 ± 0.03	1865.51 ± 713.59	330.31 ± 53.33^{b}

PR = pineapple residue; Control = beef minced meatball

Mean ± SD with different lowercase superscripts in each column are significantly ($p < 0.05$) different; ns = not significantly ($p > 0.05$) different

Table 3. Sensory liking of the beef minced meatball and plant-based minced meatball with different pineapple residue ratios

Treatments	Appearance	Color	Odor^{ns}	Taste	Firmness	Overall liking
Control	6.76 ± 1.35^{a}	6.72 ± 1.46^{a}	6.62 ± 1.63	6.72 ± 1.58^{a}	6.92 ± 1.45^{a}	6.92 ± 1.41^{a}
0% PR	6.06 ± 1.48^{a}	6.06 ± 1.39^{b}	6.04 ± 1.31	6.12 ± 1.71^{b}	5.86 ± 1.52^{b}	5.92 ± 1.47^{c}
5% PR	6.16 ± 1.49^{b}	6.20 ± 1.12^{b}	6.36 ± 1.27	6.54 ± 1.34^{ab}	6.26 ± 1.45^{b}	6.54 ± 1.32^{ab}
10% PR	6.22 ± 1.22^{b}	5.94 ± 1.25^{b}	6.06 ± 1.28	6.46 ± 1.30^{ab}	6.26 ± 1.26^{b}	6.28 ± 1.23^{ab}
15% PR	6.46 ± 1.40^{ab}	6.26 ± 1.31^{b}	6.46 ± 1.34	6.18 ± 1.44^{b}	6.32 ± 1.11^{b}	6.14 ± 1.20^{bc}
20% PR	6.26 ± 1.23^{b}	6.24 ± 1.22^{b}	6.36 ± 1.24	6.02 ± 1.60^{b}	6.32 ± 1.13^{b}	6.34 ± 1.08^{bc}

PR = pineapple residue; Control = beef minced meatball

Mean ± SD with different lowercase superscripts in each column are significantly ($p < 0.05$) different; ns = not significantly ($p > 0.05$) different

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Table 4. Nutritional values of developed plant-based minced meatballs and commercial minced meatballs based on 100 g

Nutritional values	Developed plant-based minced meatballs	Beef minced meatballs from brand A	Plant-based minced meatballs from brand B
Total energy (kcal)	128.82 ± 1.70	228.00	239.32
Moisture (g)	69.47 ± 0.22	N/A	N/A
Protein (g)	3.68 ± 0.01	17.90	15.70
Total fat (g)	2.82 ± 0.12	15.20	17.40
Carbohydrate (g)	22.18 ± 0.17	4.50	N/A
Dietary fiber (g)	8.72 ± 0.01	1.10	2.50
Ash (g)	1.85 ± 0.06	N/A	N/A
Sodium (mg)	293.99 ± 11.85	840.00	413.00

Note: N/A**,** Product's nutrition fact label is not found.

plant-based meat products. In addition to improving the nutritional values, producing plant-based meat products from pineapple by-products is an effective solution to increase dietary fiber in diets, reduce global warming, and increase food security in the future.

Ethics statements

This study was approved by the Ethics Committee of Suan Sunandha Rajabhat University (Approval no. COE. 1-088/2021).

Conflict of interest

The authors declare no conflict of interest.

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References

Damasceno, K. A., Gonçalves, C. A. A., Pereira, G. D. S., Costa, L. L., Campagnol, P. C. B., De-Almeida, P. L., & Arantes-Pereira, L. (2006). Development of cereal bars containing pineapple Peel flour (*Ananas comosus L.* Merril). Journal of Food Quality, 39(5), 417-424. doi: 10.1111/jfq.12222

Association of Official Analytical Chemists International. (2019). Official Methods of Analysis of AOAC International (21st ed.). MD, USA: AOAC International. Retrieved from https://www.aoac.org/resources/official-methods-of-analysis-revisions-to-21st-edition/

Elleuch, M., Bedigian, D., Roiseux, O., Besbes, S., Blecker, C., & Attia, H. (2011). Dietary fiber and fiber-rich by-products of food processing: Characterisation, technological functionality and commercial applications: A review. Food Chemistry, 124(2), 411–421. doi: 10.1016/j.foodchem.2010.06.077

Estell, M., Hughes, J., & Grafenauer, S. (2021). Plant Protein and Plant-Based Meat Alternatives: Consumer and Nutrition Professional Attitudes and Perceptions. Sustainability, 13(3), 1478. doi: 10.3390/su13031478

Fernández-Ginés, J. M., Fernández-López, J., Sayas-Barberá, E., & Pérez-Alvarez, J. A. (2005). Meat products as functional foods: A review. Journal of Food Science, 70(2), R37–R43. doi: 10.1111/j.1365-2621.2005.tb07110.x

Giménez, A., Ares, G., & Gámbaro, A. (2008). Survival analysis to estimate sensory shelf life using acceptability scores. Journal of Sensory Studies, 23(5), 571–582. doi: 10.1111/j.1745-459X.2008.00173.x

Gupta, C., Prakash, D., & Nazareno, M. A. (2017). Nutraceutical potential of agri-horticultural wastes. Obesity & Control Therapies, 4 (2), 1-8. doi: 10.15226/2374-8354/4/2/00137

He, J., Evans, N. M., Liu, H., & Shao, S. (2020). A review of research on plant-based meat alternatives: Driving forces, history, manufacturing, and consumer attitudes. Comprehensive Reviews in Food Science and Food Safety, 19(5), 2639–2656. doi: 10.1111/1541-4337.12610

Hygreeva, D., Pandey, M. C., & Radhakrishna, K. (2014). Potential applications of plant based derivatives as fat replacers, antioxidants and antimicrobials in fresh and processed meat products. Meat Science, 98(1), 47-57. doi: 10.1016/j.meatsci.2014.04.006

Jiménez-Colmenero, F. (2000). Relevant factors in strategies for fat reduction in meat products. Trends in Food Science and Technology, 11(2), 56–66. doi: 10.1016/S0924-2244(00)00042-X

Kehlet, U., Pagter, M., Aaslyng, M. D., & Raben, A. (2017). Meatballs with 3% and 6% dietary fiber from rye bran or pea fiber - Effects on sensory quality and subjective appetite sensations. Meat Science, 125, 66-75. doi: 10.1016/j.meatsci.2016.11.007

Kyriakopoulou, K., Dekkers, B., & van-der-Goot, A. J. (2019). Plant-Based Meat Analogues. In C.M. Galanakis (Eds.), Sustainable Meat Production and Processing. NY, USA: Academic Press.

Lund, M. N., Heinonen, M., Baron, C. P., & Estévez, M. (2011). Protein oxidation in muscle
foods: A review. Molecular Nutrition and Food Research, 55(1), 83–95. doi: 10.1002/mnfr.201000453

Mateos-Aparicio, I., & Matias, A. (2019). Food industry processing by-products in foods. In C.M. Galanakis (Eds.), The role of alternative and innovative food ingredients and products in consumer wellness (pp. 239–280). London: Academic Press.

Meilgaard, M. C., Civille, G. V., & Carr, B. T. (1999). Sensory Evaluation Techniques (3rd ed.). Boca Raton: CRC Press.

Oostindjer, M., Alexander, J., Amdam, G. V., Andersen, G., Bryan, N. S., Chen, D., Corpet, D. E., Smet, S. D., Dragsted, L. O., Haug, A., Karlsson, A. H., Kleter, G., de-Kok, T. M., Kulseng, B., Milkowski, A. L., Martin, R. J., Pajari, A.-M., Paulsen, J. E., Pickova, J., … Egelandsdal, B. (2014). The role of red and processed meat in colorectal cancer development: a perspective. Meat Science, 97(4), 583–596. doi: 10.1016/j.meatsci.2014.02.011

Organization for Economic Co-operation and Development and Food and Agriculture Organization (OECD/FAO). (2018). OECDFAO Agricultural Outlook 2018–2027. Retrieved from https://www.fao.org/publications/oecd-fao-agricultural-outlook/2018-2027/en/

Selani, M. M., Shirado, G. A. N., Margiotta, G. B., Rasera, M. L., Marabesi, A. C., Piedade, S. M. S., Contreras-Castillo, C. J., Canniatti-Brazaca, S. G. (2016). Pineapple by-product and canola oil as partial fat replacers in low-fat beef burger: Effects on oxidative stability, cholesterol content and fatty acid profile. Meat Science, 115, 9–15. doi: 10.1016/j.meatsci.2016.01.002

Rodríguez, M. B. S., Megías, S. M., & Baena, B. M. (2003). Alimentos funcionales y nutrición óptima: ¿cerca o lejos? Revista Española de Salud Pública, 77(3), 317–331.

Szczesniak, A. S. (2002). Texture is a sensory property. Food Quality and Preference, 13(4), 215–225. doi: 10.1016/S0950-3293(01)00039-8

Turgut, S. S., Isikci, F., & Soyer, A. (2017). Antioxidant activity of pomegranate peel extract on lipid and protein oxidation in beef meatballs during frozen storage. Meat Science, 129, 111–119. doi: 10.1016/j.meatsci.2017.02.019

Whitnall, T., & Pitts, N. (2019). Global trends in meat consumption. Agricultural Commodities, 9(1), 96-99.

Yuliarti, O., Kovis, T. J. K., & Yi, N. J. (2021). Structuring the meat analogue by using plant-based derived composites. Journal of Food Engineering, 288, 110138. doi: 10.1016/j.jfoodeng.2020.110138

Zhang, J., Zhang, Y., Wang, Y., Xing, L., & Zhang, W. (2020). Influences of ultrasonic-assisted frying on the flavor characteristics of fried meatballs. Innovative Food Science and Emerging Technologies, 62, 102365. doi: 10.1016/j.ifset.2020.102365