EFFECTS OF MANDARIN FIBER ADDITION ON WATER-HOLDING CAPACITY, TEXTURE, COLOUR, AND ANTIOXIDANT CAPACITY OF LOW-FAT FRANKFURTERS

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I. INTRODUCTION

Frankfurters are popular worldwide despite being associated with cardiovascular diseases due to their high fat content. Reducing fat content by traditional processing techniques often affects water-binding ability, texture, and mouthfeel [1]. These problems could be solved by using citrus fiber as a fat substitute due to its water-binding properties [2]. Besides, citrus fiber is known for its functional and nutritional properties [3]. Mandarin a type of citrus, is widely cultivated, with China being the largest producer in 2021 (25.16 million tons). Mandarin peels abundant in insoluble fiber are therefore a candidate fat substitute. However, the specific impact of mandarin dietary fiber after pectin extraction on the structure, quality, antioxidant property, and, most notably, digestibility of frankfurters remains largely unexplored.

II. MATERIALS AND METHODS

Mandarin fiber was obtained from Fengdao Food Co., Ltd. (Shaoxing, China). Five groups of low-fat frankfurters (20% fat content) were prepared using a modified method [4], with varying concentrations of mandarin fiber (0%, 1%, 2%, 3%, and 4%). The batters were made with 30% ice water, 2.2% salt, 0.3% compound phosphate, and 0.015% sodium nitrite. The batters were then vacuum stuffed into approximately 20-mm-diameter natural casings (sheep intestines) and hand-linked to form 15 cm long links. The meat batters were heated in a water bath at 75 ± 2 °C for 30 min, followed by cooling in water at 21 °C. Then the pH value, moisture, crude protein, fat, and ash contents of the frankfurters were determined. Cooking loss was measured, and texture profile analysis was conducted following a published method [5]. Colour coordinates were determined using the CIELAB system [6]. Antioxidant effects were assessed using the ferric reducing antioxidant power (FRAP) assay and the thiobarbituric acid reactants (TBARS) colorimetric assay. Sequential digestion of the stomach and intestine was simulated using an *in vitro* digestion model. Protein digestibility was measured after gastric and intestinal digestion using a published method [7]. All measurements were subject to statistical analysis using one-way ANOVA followed by Tukey's post hoc test with $P < 0.05$ being considered as statistical significance.

III. RESULTS AND DISCUSSION

The addition of mandarin fiber improved water-holding capacity, reduced cooking loss, and increased yield in sausages. Cooking loss initially decreased with increasing fiber amounts, reaching a minimum at 3% before increasing again due to fiber's water-absorbing properties. Fiber addition created chamber structures in the protein gel network, enhancing stability and water-holding capacity. Excessive fiber addition increased pore size, limiting further water-holding capacity. Texture analysis showed significant improvements in hardness, cohesiveness, gumminess, chewiness, and resilience with different proportions of mandarin fiber. Mandarin fiber affected sausage colour, reducing brightness (L^* value) and increasing redness (a^* value) and yellowness (b^* value), particularly at a 2% addition level. These colour changes may be attributed to variations in flavonoids within mandarin fiber during heating, resulting in more vibrant sausages and improved sensory quality. Additionally, mandarin fiber enhanced the antioxidant capacity of low-fat sausages, especially at 2% and 3% addition levels, demonstrated by increased ferric reducing antioxidant power and inhibition of thiobarbituric acid reactants. These effects can be attributed to the presence of antioxidant polyphenolic compounds in mandarin fiber. Remarkably, higher amounts of mandarin fiber correlated with an increase in protein digestibility of the sausages. Furthermore, mandarin fiber slightly decreased the pH value. This lower pH value inhibited microbial growth to some extent, affecting the shelf life of meat products. However, excessively low pH values could impact the gelation properties of proteins, affecting sausage texture. Therefore, the addition of mandarin fiber to low-fat sausages should be done in moderation.

Table 1. Texture of low-fat frankfurters

Concentrations of mandarin fiber (%)	Hardness	Cohesiveness	Gumminess	Chewiness	Resilience
0	5067[c]	0.77[a]	3908[c]	3402[c]	0.41[a]
1	5421[c]	0.75[bc]	4038[c]	3521[c]	0.38[b]
2	7540[b]	0.76[b]	5697[b]	4971[b]	0.39[b]
3	9141[a]	0.74[cd]	6726[a]	5813[a]	0.37[c]
4	10174[a]	0.73[d]	7430[a]	6288[a]	0.36[c]
SEM	326	0.004	240	198	0.003
P-value	<0.001	<0.001	<0.001	<0.001	<0.001

SEM: standard error of means; Labelled means without a common letter differ.

IV. CONCLUSION

In conclusion, adding mandarin fiber to low-fat frankfurters improved water-holding capacity, reduced cooking loss and pH values, and enhanced texture properties such as hardness, gumminess, chewiness, cohesiveness and resilience. Mandarin fiber positively affected sausage colour, increasing redness and yellowness while reducing brightness. Furthermore, it enhanced the antioxidant capacity of low-fat sausages, especially at 2% and 3% addition levels.

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