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The Effect of Adding Sodium Tripolyphosphate on the Physical and Sensory Characteristics of Meatballs Formulated with Dragon Fruit Peel and Oyster Mushroom Blend

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A B S T R A C T

This study aimed to determine the best addition of Sodium Tripolyphosphate (STPP) to produce chicken meatballs containing dragon fruit peel and oyster mushroom with desirable physical and organoleptic characteristics. The research used a Completely Randomized Design (CRD) with treatments of STPP addition (0%, 0.1%, 0.2%, and 0.3% w/w) with four replications. The data were analyzed using ANOVA and the DMRT test at the 5% level. The results showed that the best treatment was the addition of 0.3% STPP, which produced meatballs with the following characteristics: physical properties (hardness 36.26 N; springiness 0.82; cohesiveness 0.58; chewiness 1333.5), water holding capacity of 71.7%, and organoleptic scores of taste 2.47 (savory), aroma 3.53 (characteristic chicken aroma), and texture 3.73 (chewy).

Contribution to Sustainable Development Goals (SDGs):
SDG 2: Zero Hunger
SDG 9: Industry, Innovation and Infrastructure
SDG 12: Responsible Consumption and Production

1. INTRODUCTION

1.1. *Research Background*

Meatballs are an oil-in-water (o/w) emulsion, with fat as the dispersed phase, water as the continuous phase, and myofibrillar protein as the emulsifier [1]. They are processed from ground meat (beef, chicken, pork, or fish), mixed with flour, seasonings, and other finely comminuted ingredients, and then boiled until cooked [2]. Typically, meatballs have a savory flavor and a characteristic round, firm, and chewy texture.

Chicken meatballs are a type of meatball primarily made from chicken meat, with fillers and other seasonings added, then shaped into spheres and boiled until cooked. The incorporation of dragon fruit peel and oyster mushroom into chicken meatballs can enhance their organoleptic characteristics. Conventional chicken meatballs often have a pale colour and a less chewy texture, making them less appealing to consumers. Therefore, the addition of dragon fruit peel and oyster mushroom is necessary to improve the sensory attributes of colour and texture. Dragon fruit peel is a source of antioxidants (anthocyanins), while oyster mushroom contains fibre, minerals, and protein. Previous research [2] indicated that the best formulation for chicken meatballs used a dragon fruit peel-to-oyster mushroom ratio of 1:2. However, the resulting meatballs were still suboptimal, being too soft and lacking the characteristic chewiness of beef meatballs. Consequently, sodium tripolyphosphate (STPP) must be added as a texturizing agent.

Sodium tripolyphosphate (STPP) is a food additive regulated by the Indonesian Food and Drug Authority (BPOM) under Regulation No. 29 of 2023. STPP was selected as a texturizing agent in this study based on several key advantages its consumption is recognized as safe within established limits, it is relatively inexpensive, and it effectively enhances the texture of meat products by increasing their firmness and chewiness. This study aimed to determine the best addition of Sodium Tripolyphosphate (STPP) to produce chicken meatballs containing dragon fruit peel and oyster mushroom with desirable physical and organoleptic characteristics.

1.2. Literature Review

According to [3], meatballs are processed meat products made from livestock meat mixed with starch and seasonings, with or without the addition of other food ingredients and/or permitted food additives, shaped into spheres or other forms, and then cooked. Ideally, meatballs are made with chicken at pre-rigour mortis to achieve a compact, chewy texture. However, chicken meat available in the market is generally in a post-rigour state. Therefore, to optimally extract actin and myosin, the use of a chemical additive such as sodium tripolyphosphate (STPP) is necessary [4]. The fundamental principles of meatball production involve meat communition, dough formation, and cooking [5].

Food additives used to improve texture and chewiness are known as texturizing agents. The addition of these agents functions as a stabilizer, improves texture, and enhances water holding capacity [6]. Textural improvement in meatballs can be achieved by adding additives that interact with calcium ions, such as sodium tripolyphosphate (STPP). STPP is a permitted food additive containing phosphate salts and minerals. This compound is known as tripolyphosphate because STPP possesses three phosphate atoms. The mechanism of STPP addition changes the dough's pH because its base ionization constant is greater than its acid ionization constant. At higher pH, the negative charges on meat proteins (actin and myosin) increase, causing the proteins to swell, thereby increasing water-binding capacity in meat products and facilitating fat emulsification [7]. Binding of phosphates with Ca^{2+}, Mg^{2+} (cross-bridges in actomyosin complex) contributes to separate actin and myosin after rigor mortis. Hence, the above-mentioned process will enhance the water-holding capacity of meat and meat products, and improve the tenderness and colour of meat. Moreover, the binding of metal ions could reduce oxidative rancidity [8]. Research by [9] indicates that using 0.3% STPP affects the resulting gel strength, thereby producing meatballs with a favourable texture.

The utilization of STPP in food products is governed by the Indonesian Food and Drug Authority (BPOM) Regulation No. 29 of 2023, which specifies a maximum permitted level of 2200 mg/kg (expressed as phosphorus) in processed meat products. Furthermore, reference [10] indicates that the approved dosage for STPP in meatball formulation is 0.3% of the total meat weight.

1.3. Research Objective

This study aims to determine the effect of STPP addition and identify the optimal amount on the physical and sensory characteristics of chicken meatballs made with dragon fruit peel and oyster mushrooms.

2. MATERIALS AND METHODS

2.1. Material and Tools

The materials used in this study were chicken meat, red dragon fruit peel, oyster mushrooms, STPP (Sodium Tripolyphosphate), "Rose Brand" tapioca flour, garlic, egg white, salt, ice cubes, and pepper. All materials were obtained from a local traditional market.

The tools used include texture analyzer, chopper, oven, desiccator, filter paper, 35 kg weight, stove, pot, bowl, spoon, knife, and ruler.

2.2. Design Experiment and Analysis

The research design used in this study was a Completely Randomized Design (CRD) with treatment variations consisting of STPP additions at 0%, 0.1%, 0.2%, and 0.3% (w/w), each replicated 4 times. The collected data were analyzed using Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) at the 5% level.

2.3. Implementation of Research

2.3.1. Meatballs processing

The meatball formulation was prepared using 100 g chicken meat, 10 g dragon fruit peel, and 20 g oyster mushroom. The mixture was comminuted with salt, ice cubes, and varying STPP additions (0%, 0.1%, 0.2%, 0.3% w/w) using a chopper. Supplementary ingredients (tapioca flour, egg white, garlic, pepper) were then incorporated and homogenized. The dough was shaped into spheres and boiled at 100°C for 15 minutes until flotation occurred. Cooked meatballs were drained and cooled to room temperature for analysis.

2.4. Observation

2.4.1. Physical Analysis

The analyzed parameters included texture profile (hardness (N), springiness, cohesiveness, chewiness) and water holding capacity (%).

2.4.2. Sensory Analysis

Organoleptic testing of the chicken meatball samples was performed using a scoring method. In this organoleptic test, 15 panellists provided assessments of the taste, aroma, and texture of the meatballs. Each parameter used a distinct 5-point scoring scale (1-5).

Table 1. Meatball scoring scale criteria

Scale	Taste	Aroma	Texture
1	Bland	Unappetizing	Mushy
2	Slightly savory	Slightly chicken aroma	Slightly mushy
3	Savory	Chicken aroma	Chewy
4	Very savory	Strong chicken aroma	Very chewy
5	Extremely savory	Extremely chicken aroma	Extremely chewy

3. RESULT AND DISCUSSION

3.1. Physical Analysis of Meatballs

3.1.1. Texture (hardness, springiness, cohesiveness, chewiness)

Hardness is defined as the maximum force required for the first bite [2]. Analysis of variance revealed that STPP addition treatments significantly influenced ($p \leq 0.05$) the hardness of the meatballs. As shown in **Fig. 1, increasing additions of STPP resulted in a significant increase in meatball hardness**.

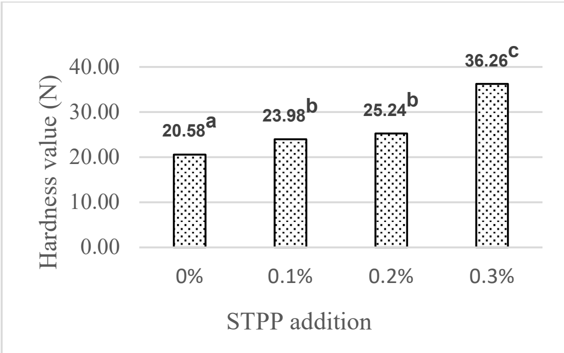

Fig. 1. Effect of STPP addition on meatball hardness

The highest hardness value for the meatballs (36.26 N) was observed with 0.3% STPP, while the lowest (20.58 N) was observed in the control sample with 0% STPP. STPP increases the pH of meat, leading to protein swelling. The swollen meat proteins optimally trap water molecules, resulting in a dense and firm gel structure. This phenomenon significantly contributes to the increase in hardness. These findings align with previous research [11], which showed that adding 0.3% (w/w) STPP to yellow pumpkin chicken meatballs significantly enhanced hardness compared to the control sample. According to [12], STPP elevates meat pH, thereby releasing positive charges and creating a surplus of negative charges. This leads to repulsion between protein filaments, creating more space for strong water binding. During the cooking process, this tightly bound water forms a dense and stable protein gel, ultimately producing firm meatballs with minimal shrinkage.

Table 2. Springiness of meatballs with different STPP addition

STPP Addition Treatment (% w/w)	Springiness Mean ± SD
0	$0.77^{a} \pm 0.02$
0.1	$0.80^{a} \pm 0.01$
0.2	$0.81^{a} \pm 0.01$
0.3	$0.82^{a} \pm 0.01$

Springiness in meatballs relates to gel strength, which measures how quickly a sample returns to its original shape after the applied force is removed [13]. **Table 2 shows that increasing the amount of STPP added** did not significantly affect the springiness of the meatballs. According to [7], springiness values are influenced by the amount and type of starch used in meatball production. Gelatinization in meatballs involves both starch and protein gelatinization; however, starch gelatinization plays a dominant role in determining springiness. In this study, the starch used was tapioca flour, with the same quantity (a fixed variable) across all treatments, thus resulting in no significant differences in springiness (elasticity) values. These findings align with research by [14], which indicated that adding 0.3% STPP yielded a springiness value (0.75 kg/kg) that was not significantly different from that of the 0% STPP treatment (0.71 kg/kg).

Cohesiveness is a parameter that measures the extent to which a material can deform before breaking, or how much a substance can be compressed between the teeth [15]. Analysis of variance results indicated that the STPP addition treatment significantly affected ($p \leq 0.05$) the cohesiveness of the meatballs.

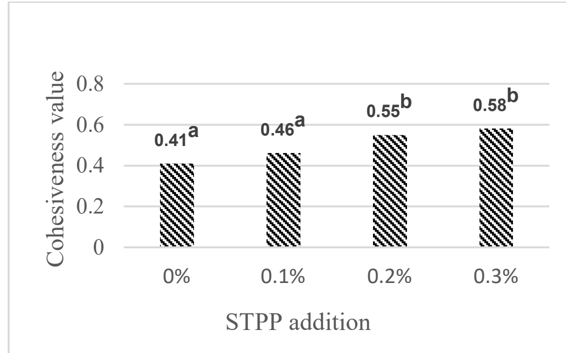

Fig. 2. Effect of STPP addition on the cohesiveness

As shown in **Fig. 2,** higher additions of STPP significantly increased the cohesiveness value of the meatballs. The highest cohesiveness value (0.58) was observed with 0.3% STPP addition, while the lowest value (0.41) was found in the control treatment (0% STPP). STPP strongly interacts with the actomyosin complex through its chelation properties (metal-ion binding), enabling meat proteins to form a compact gel network. Research by [9] reported that the addition of 0.3% STPP significantly affected the cohesiveness value of patin fish meatballs compared to the control (0% STPP). According to [16], the ability of di- and triphosphates to remove the structural barricade and chelate protein-bound Mg2+ and Ca2+ within meat proteins, releasing myosin, which can act as a natural emulsifier. More proteins could be extracted and help stabilize the protein matrix, in which fat and water are trapped. The chelation effect on proteins increases the meat's ionic strength, resulting in a more compact meatball structure.

Chewiness represents the ability of meatballs to return to their original shape after chewing, exhibiting a springy texture and resistance to disintegration. Chewiness shows positive correlation with hardness, cohesiveness, and gel strength in meatballs [17].

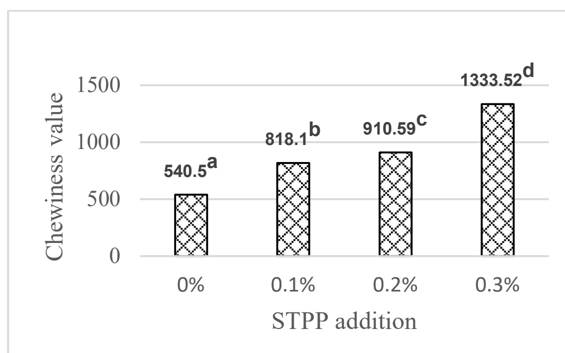

Fig. 3. Effect of STPP addition on meatball chewiness

Analysis of variance revealed that STPP addition treatments significantly influenced ($p \leq 0.05$) the chewiness of the meatballs. As shown in **Fig. 3,** increasing STPP additions resulted in a significant enhancement of chewiness values. The highest chewiness value was observed in meatballs with 0.3% STPP (1333.52), while the lowest was in the control sample with 0% STPP (540.5). This can be attributed to STPP's ability to interact with positively charged sites on protein molecules, thereby strengthening intramolecular protein bonds and improving water-holding capacity. According to a previous study [18], the addition of STPP significantly increased the chewiness of chicken meatballs compared with samples containing other texturizing

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agents. This effect occurs because STPP enhances ionic bonds, thereby increasing water-binding capacity. As the water-binding capacity improves, the chewiness of the meatballs also increases. The enhancement of chewiness through STPP addition is positively correlated with improvements in other texture profile attributes, namely hardness, springiness, and cohesiveness.

3.1.2. Water Holding Capacity (WHC)

Water-holding capacity (WHC) refers to the ability of meat to retain its inherent water content when subjected to external forces, such as cutting, heating, grinding, and pressure [17]. Analysis of variance indicated that the addition of STPP had a significant effect ($p \leq 0.05$) on the water holding capacity of the meatballs.

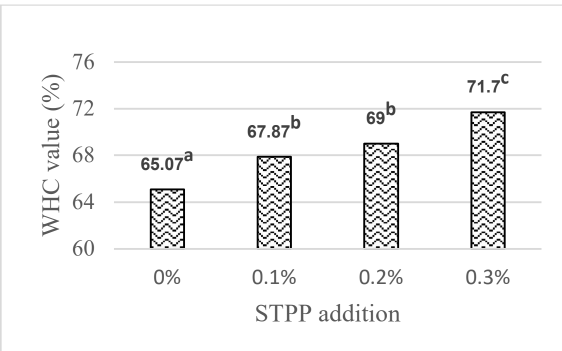

Fig. 4. Effect of STPP addition on meatballs WHC

As shown in **Fig. 4, increasing additions of STPP resulted in a significant improvement in the water-**holding capacity of the meatballs. This phenomenon occurs because STPP can dissolve myofibrillar proteins, particularly myosin. The extracted proteins, which act as binding agents, interact with one another, leading to increased spacing between filaments. This expanded structure enhances water retention, thereby increasing the water-holding capacity. These findings align with previous research [7], which found that higher levels of STPP significantly enhanced the water-holding capacity of beef meatballs. The mechanism involves phosphate compounds in the meat mass, which improve the water-binding capacity of meat proteins through several actions. Alkaline phosphates increase the pH, which disrupts the bonds between protein groups (actin, myosin), facilitating water binding. Furthermore, the properties of polyphosphate ions promote muscle fiber swelling and activate proteins. These activated proteins can optimally bind and trap water molecules [8].

3.2. Sensory Analysis of Meatballs

Table 3. Mean organoleptic scores from scoring test

STPP Addition Treatment (% w/w)	Taste ± SD	Aroma ± SD	Texture ± SD
0	$2.67^{a} \pm 0.72$	$3.07^{a} \pm 0.70$	$1.47^{a} \pm 0.63$
0.1	$2.60^{a} \pm 0.73$	$3.00^{a} \pm 0.84$	2.27 ± 0.88
0.2	$2.70^{a} \pm 0.61$	$3.47^{a} \pm 0.83$	2.60 ± 0.82
0.3	$2.47^{a} \pm 0.83$	$3.53^{a} \pm 0.83$	$3.73^{c} \pm 0.70$

Analysis of variance in Table 3 indicates that the addition of STPP did not significantly affect the meatball taste scores. This can be attributed to the relatively small differences in STPP addition levels, which were insufficient to influence the perceived taste. Furthermore, STPP is inherently tasteless. These findings align with previous research [11], which reported that adding sodium tripolyphosphate (STPP) did not affect the taste of chicken meatballs with yellow pumpkin, as STPP is flavourless. The primary factors influencing meatball taste depend on the freshness of the main ingredient (chicken) and the quantity of supporting ingredients, such as seasonings.

Analysis of variance in **Table 3.** shows that STPP addition did not significantly affect the aroma scores of the meatballs. STPP does not contain volatile components that could alter the meatball's aroma. This finding is consistent with [19], which reported that STPP addition did not significantly affect the aroma scores of Mechanically Deboned Meat (MDM) meatballs, as STPP lacks volatile groups that could impart a distinct aroma. The components that most significantly influence meatball aroma are the filler ingredients (seasonings used), meat quality, and cooking temperature.

Analysis of variance in **Table 3.** indicates that STPP addition significantly influenced ($p \leq 0.05$) the texture scores of the meatballs. The treatment with 0.3% STPP yielded the highest texture score of 3.73 (chewy), while the 0.1% STPP treatment yielded the lowest texture score of 1.47 (very soft). This suggests that consumers prefer meatballs with a chewy texture over those with a soft texture. These results align with previous research [19], which found that adding 0.3% STPP to MDM meatballs resulted in average scores ranging from slightly to like. Based on these findings, it can be concluded that the panellists preferred meatballs with a moderately chewy yet firmer texture.

3.3. Analysis of the Optimal Decision

The optimal treatment for chicken meatballs containing dragon fruit peel and oyster mushroom with STPP addition was selected using the De Garmo method. The greater the weight of a variable, the higher its level of importance [20]. This involved comparing physical quality parameters (texture: hardness, springiness, cohesiveness, and chewiness) and organoleptic characteristics (taste, aroma, and texture). The best results were achieved with the addition of 0.3% STPP, which yielded meatballs with a firm and chewy texture (hardness 36.26 N; springiness 0.82; cohesiveness 0.58; chewiness 1333.5), water holding capacity of 71.7%, and organoleptic scores of 2.47 (savory) for taste, 3.53 (chicken aroma) for aroma, and 3.73 (chewy) for texture.

4. CONCLUSION

The addition of STPP significantly influenced texture parameters (hardness, cohesiveness, and chewiness), water-holding capacity, and organoleptic characteristics (texture). However, it did not affect springiness, taste, or aroma substantially. The treatment with 0.3% STPP was identified as the optimal addition, producing chicken meatballs with dragon fruit peel and oyster mushroom that exhibited the following characteristics: texture profile (hardness 36.26 N, springiness 0.82, cohesiveness 0.58, chewiness 1333.5), water holding capacity of 71.7%, and organoleptic scores of 2.47 (savory) for taste, 3.53 (characteristic chicken aroma) for aroma, and 3.73 (chewy) for texture.

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