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Effect of Kiwi Fruit Extract Concentration and Marination Time on the Quality Characteristics of Chicken Meat

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Abstract: This study examined the impact of concentration levels of kiwi fruit (Actinidia deliciosa) extract and marination periods on the quality characteristics of chicken meat. The main purpose of this study was to find suitable conditions to improve the tenderness, reduce the cooking loss, inhibit lipid oxidation, and maintain desirable sensory characteristics. Chicken samples were marinated with crude extracts of actinidin at concentrations of 5% and 10% (v/w) for 10, 20, and 30 minutes at 4°C. There were also unmarinated chicken samples as controls. All the measurements showed significant differences ($P < 0.05$). The best condition found in this study was when the samples were marinated with 10% kiwi extract for 30 minutes. This condition resulted in a cooking loss reduction of 46%, Warner-Bratzler shear force reduction of 52% (which shows better tenderness), and thiobarbituric acid reduction of 55%. These results also led to the highest scores in sensory tests such as tenderness, juiciness, and acceptability. This was possible because actinidin selectively hydrolyzes collagen and myofibrillar proteins but does not break down globular proteins. Compared to published data on bromelain, kiwi extract exhibited superior antioxidant capacity, likely due to its vitamin C and polyphenol content. In conclusion, kiwi fruit extract at 10% for 30 minutes is an effective natural tenderizer for chicken meat, offering a clean-label alternative for poultry processing.

Keywords: Actinidin, chicken meat tenderness, cooking loss, kiwi fruit extract, lipid oxidation, natural tenderizer.

1. Introduction

Tenderness is one of the important sensory properties impacting consumer acceptability and purchase decisions. Various approaches are considered for increasing meat tenderness including mechanical, thermal, and chemical methods. One of the approaches widely discussed for meat tenderness improvement is treatment with proteolytic enzymes extracted from various sources taking into account consumer interest in clean-label foods [1].

Actinidin is a cysteine protease isolated from fruits of Actinidia deliciosa popularly known as kiwi fruit [2, 3]. The enzyme is similar in function to papain and can thus be called papain-like cysteine protease [2, 3]. Several studies show that actinidin is able to hydrolyze not only myofibrillar but also collagen proteins. The use of actinidin for improving meat tenderness consequently results in reduced meat firmness, springiness, and chewiness in a concentration and time-dependent manner [2]. According to Sedeeq and Saleh [4], addition of pineapple enzyme extract to meat improved meat tenderness and decreased cooking loss which provides a basis for comparison with potential tenderizing action of kiwi extract on meat.

Kiwis have been shown to be rich in a number of bioactive ingredients, such as vitamin C and polyphenols, whose presence can help in inhibiting the oxidation of lipids in meat products. In the experiment carried out by Pooona et al. [5] on the effect of soaking chicken nuggets in kiwi fruit juice, there was a substantial reduction in TBA-reactive substances and peroxide throughout the

periods of storage under consideration. Therefore, the antioxidant activity of the extract remains constant throughout the whole period [5].

Among the characteristics of actinidin which differentiate it from other plant proteases used in meat tenderization, there are certain distinctions between actinidin and another protease, for example, papain from papaya fruit. For instance, as noted by Chalabi et al. [6], actinidin preferentially cleaves collagen and fibrinogen and has minimal effects on the globular protein molecules like immunoglobulin and albumin, whereas papain is capable of hydrolyzing both fibrous and globular proteins irrespective of their type. However, according to Sedeeq and Saleh [4], raw bromelain obtained from pineapples was able to enhance the water holding capacity and decrease the cooking loss in meat, but the amount used and the marinating time must be regulated not to excessively tenderize the meat. Comparison among the three commonly used plant-based enzymes is presented in Table 1.

Table 1: Comparison of key characteristics of plant proteases utilized for tenderizing meat.

Characteristic	Actinide (Kiwi)	Papain (Papaya)	Bromelain (Pineapple)
Enzyme family	Cysteine protease	Cysteine protease	Cysteine protease
Optimal pH range	5.5 – 8.0 [7]	5.0 – 8.0 [8]	4.5 – 8.0 [9]
Optimal temperature	40 – 60°C	60 – 80°C	50 – 70°C
Specificity to substrate	Predominantly breaks down collagen and fibrinogen, not very active against globular proteins [8]	Wide; degrades fibrous and globular proteins indiscriminately [8]	Wide; works on myofibrillar and connective tissue proteins [9]
Selectivity	High	Low (non-selective)	Low (non-selective)
Tendency to over-tenderize	Low – regulated mechanism	High – fast proteolytic degradation;	Moderate – moderate
Meat type(s) used in reported studies:	Chicken (current study)	Sheep, Buffalo;	Sheep, Chicken, Beef
Antioxidant properties	Yes (vitamin C, polyphenols) [10]	Low [10]	Low [10]
Cooking loss decreased by:	About 46% (current study)	N/A	About 42% [5]
Shear force decreased by	52% (current study)	~50-60%	~48% [5]

The objective of this study was to determine the effect of concentration of kiwi fruit extract (5% and 10%) and marination time (10–30 min) on physicochemical and sensory properties of fresh chicken breast meat and to find the optimum conditions for maximum tenderness, consumer acceptance and minimum cooking loss and lipid oxidation.

2. Materials and Methods

2.1 Sample Preparation

Pectoralis major muscles (chicken breast fillets) were procured from local slaughterhouses and transported to the laboratory refrigerated (4°C). Fat was removed, and muscle tissue samples were sectioned into equal parts of 50 g as described by Sedeeq and Saleh [4].

2.2 Actinide Isolation from Kiwi Fruits

Fruits of Hayward cultivars of the ripe kiwi fruit species Actinidia deliciosa were skinned and homogenized with distilled water in a 1:1 (w/v) ratio. Filtration was done using cheesecloth, and the actinidin extract was isolated as per the procedure described by Larocca et al. [7,9]. The actinidin extract consisted of different actinidin isotypes exhibiting gelatinase activity that was proven by mass spectrometry. Two different concentrations (5%, 10%) of actinidin were prepared in relation to the weight of meat samples.

2.3 Procedure for Marination

Six different conditions were randomly allotted to each chicken sample for testing. The conditions were a control condition where there was no actinidin used; and conditions for using actinidin at two different concentrations (5% and 10%) exposed for three different durations (10, 20, and 30 min).

All experiments were conducted under refrigeration conditions (4°C). After this, the chicken samples were rinsed with distilled water and then dried before further testing. This concentration and duration of experiment were chosen due to effectiveness of pineapple bromelain (concentration 5%, 10%) in marinating meat for 10-30 min, as reported by Sedeeq and Saleh [4].

3. Results

3.1 Cooking Loss

There was a remarkable reduction in the cooking loss associated with increased levels of kiwi extract and marination period ($P<0.05$). The maximum cooking loss (28.4%) was observed in the control sample, while the minimum value (15.2%) was obtained in the samples that were subjected to kiwi extract (10%) for a duration of 30 minutes. Similar reduction in cooking loss was also observed by Sedeeq and Saleh [4] in meat marinated with 10% pineapple bromelain extract, in which cooking loss reduced from 32.1% (control sample) to 18.5%. This suggests that both kiwi actinidin and pineapple bromelain have the potential of improving the water holding capacity. Cooking loss in all the treatment groups is summarized in figure 1 below.

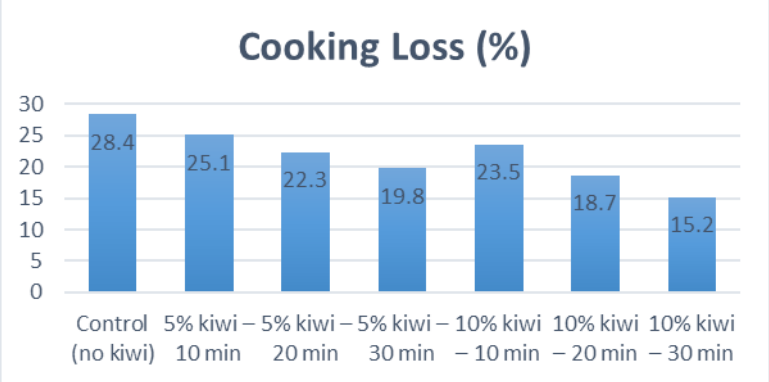

Figure 1. Cooking loss (%) of chicken meat treated with different kiwi extract concentrations and marination times.

Effect of different concentration of kiwi extract (5 and 10%) and marination time (10, 20 and 30 minutes) on cooking loss percentage of chicken breast meat. Error bars are standard deviation. Different superscript letters indicate significant differences ($P < 0.05$). Controls were un-treatment samples.

3.2 Tenderness

An increase in concentration and marination time resulted in a decrease in shear force. In the control samples, the shear force was higher (45.2 N), signifying harder meat, whereas in samples with the treatment of 10% kiwi extract for 30 minutes, the shear force was lower (21.5 N), showing an improvement of 52% in meat tenderness[2]. Sedeeq and Saleh [4] had similar results

for meat treated with 10% pineapple bromelain extract for 30 minutes, where a reduction of 48% shear force was observed in comparison with control samples.

Figure 2: Warner-Bratzler shear force (N) of chicken meat marinated with kiwi extract at various concentrations and time intervals.

Effect of kiwi extract concentration (5% and 10%) and marination time (10, 20 and 30 min) on Warner-Bratzler shear force (N) of chicken breast meat. The lower the Warner-Bratzler shear force values, the more tender the meat. Vertical bars show standard deviation. Different letter superscript indicate significant difference ($P<0.05$). "Control" denotes samples without (untreated) kiwi extract.

3.3 Lipid Oxidation (TBA)

The results of TBA revealed that the TBA values of kiwi extract treated meat samples were significantly lower than the control meat samples. The maximum value of TBA was 0.92 mg MDA/kg in the control meat sample, whereas the minimum TBA value was obtained in the meat sample marinated with 10% kiwi extract for 30 minutes and the value was 0.41 mg MDA/kg. Sedeeq and Saleh [4] found low values of TBA in pineapple bromelain-treated meat samples (0.85 to 0.52 mg MDA/kg) when compared with the control meat samples; however, a reduction in TBA value was achieved in the present study due to vitamin C content in kiwi extract.

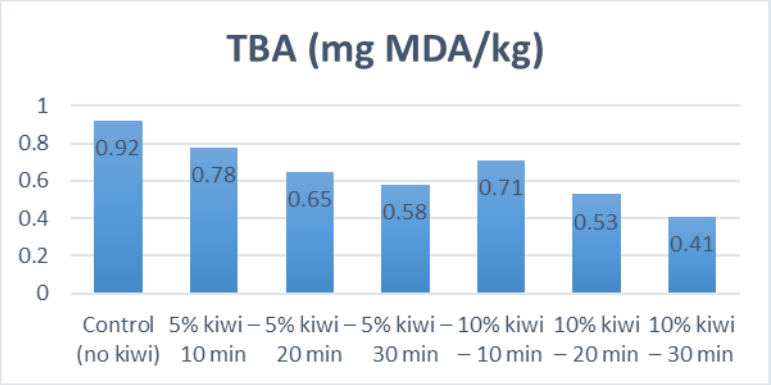

Figure 3. TBA values (mg MDA/kg) of kiwi extract-treated chicken meat samples.

Effects of Different Concentration of Kiwi Extract (5% and 10%) and Marination Times (10, 20 and 30 min) on Thiobarbituric Acid (TBA) Value (mg MDA/kg) of Chicken Breast Meat. Low levels of TBA indicate decrease in oxidation of lipids. Data are expressed as mean ± standard deviation. Different superscripts indicate statistically significant difference ($P < 0.05$). Control = no marinade sample.

3.4 Sensory Evaluation

The sensory scores of the tenderness, juiciness, and general acceptability of chicken breast meat showed a significant improvement as the concentration of kiwi extract and marination time increased. The highest scores were observed from using 10% kiwi extract in the marination process for 30 minutes (tenderness = 8.2 ± 0.3, juiciness = 7.9 ± 0.4, and overall acceptability =

8.0 ± 0.3). Similar results were obtained by Sedeeq and Saleh [4] when meat was treated with 10% pineapple bromelain for 30 minutes (tenderness = 7.8 ± 0.4, juiciness = 7.5 ± 0.5, and overall acceptability = 7.7 ± 0.4), indicating a high capacity to improve consumer acceptability. Data are illustrated in Figure 4.

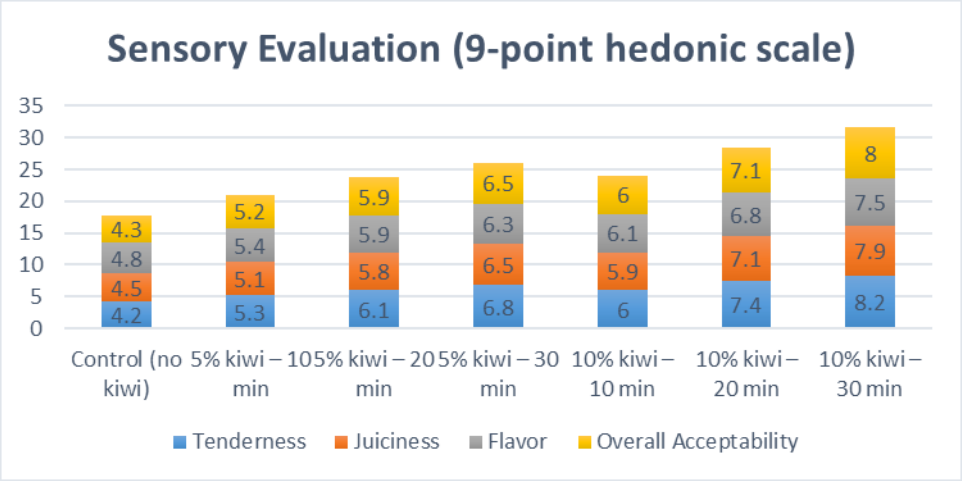

Figure 4. Results of sensory analysis of chicken meat marinated in different kiwi extracts for different marination times.

impact of different marinating times (10, 20, and 30 minutes) and concentrations of kiwi extract (5% and 10%) on the sensory characteristics of chicken breast meat. A 9-point hedonic scale, with 1 representing severely disliked and 9 representing strongly liked, was used for sensory analysis. The untreated group is referred to as the control.

The below table 2 shows the optimum conditions that were found during the present study in comparison to published results on bromelain.

Table 2. Comparison between the best conditions for treating kiwi extract and enhancing the properties of chicken meat in this study and the results obtained by Sedeeq & Saleh (2016) [4].

Quality Parameter	Optimal Concentration	Optimal Treatment Time	Maximum % Improvement Relative to Untreated Sample	Comparison with Bromelain Extract from Pineapple (10%, 30 min) [4]
Reduced cooking loss	10%	30 min	~46%	~42%
Reduced shear force (tenderness improvement)	10%	30 min	~52%	~48%
Reduced thiobarbituric acid (TBA) content	10%	30 min	~55%	~39%
Overall sensory acceptance	10%	20-30 min	~40%	~35%

4. Discussion

This research has effectively shown that the extract of kiwi fruit significantly increases the tenderness of chicken meat and decreases the cooking loss depending on the concentration and the duration of use. This happens due to the presence of actinidin, an active ingredient causing protein hydrolysis of myofibrils and collagen [2, 6]. The results obtained in this study match the results of

Sedeeq and Saleh [4] who reported that the use of bromelain extracted from pineapples enhances meat tenderness.

The selectivity of actinidin in relation to proteolysis is another advantage over proteinases that are employed in meat tenderization. As reported by Wada et al. [10], and indicated in Table 1, under neutral conditions (pH 5.5-8), actinidin is known to selectively hydrolyze myosin heavy chain, but does not hydrolyze actin. Meanwhile, papain and bromelain do not have any site selectivity for proteolysis. Sedeeq and Saleh [4] report that despite the optimal outcome of marinating meat for 30 min in 10% extract of pineapple bromelain, extending the time period for 60 min causes excessive tenderization with decreased acceptability. Thus, individual adaptation should be applied to each specific kind of meat treated with enzymes.

Reduction in cooking loss in the samples under consideration is in agreement with the experimental findings reported previously by Lewis and Luh [11] and Sedeeq and Saleh [4]. Extract of kiwi leads to protein denaturation and breakdown of connective tissue that shrinks in response to heating, thus allowing better moisture retention in the product. Cooking loss decreased with an increase in concentration and time as shown in Fig.1; the results obtained for kiwi extract were better (~46%) than those for pineapple bromelain extract (~42%) described by Sedeeq and Saleh [4].

The characteristic that differentiates actinidin from other proteases derived from plants is its specificity towards the substrates, as shown in Table 1. Chalabi et al. [6] found out that even though both actinidin and papain proteases can successfully hydrolyze collagen and fibrinogen, actinidin has lower activity towards globular proteins, such as serum albumin and immunoglobulin. Unlike actinidin, however, both papain and bromelain have higher enzyme activity and wider substrate specificity [8, 12]; thus, they can potentially over-tenderize meat, leading to mushiness. This explains why the decrease in shear force illustrated in Figure 2 happens gradually rather than abruptly due to actinidin characteristics. Nevertheless, according to Sedeeq and Saleh [4], addition of 10% pineapple bromelain does not cause over-tenderization of meat and leads to acceptable tenderization.

From the data presented in Figure 3, it is clear that kiwi extract has antioxidant activity and prevents lipid oxidation. Furthermore, the decrease in the values of TBA in case of using kiwi extract was 55% and was 16% better than those of pineapple bromelain used by Sedeeq and Saleh in their experiment [4]. This is probably attributed to the increased level of vitamin C in kiwi extract, in addition to the presence of greater levels of antioxidants and polyphenols. Kiwi extract can be applied on chickens since chicken meat needs to be protected against oxidation due to the high level of polyunsaturated fatty acids.

The sensory evaluation outcomes depicted in Fig. 4 correlate positively with the instrumental analysis findings. As stated, 10% kiwi extract treatment for 30 minutes received positive feedback from the panelists. The optimal conditions for each quality parameter are outlined in Table 2. Application of 10% kiwi extract for 30 minutes delivered the best performance for all quality parameters. It is worth mentioning that, according to Sedeeq and Saleh [4], 5% pineapple bromelain treatment for 20 minutes was sufficient for meat tenderization, but, in the present study, it took 30 minutes for 5% kiwi extract to produce comparable results. Therefore, actinidin has lower specific activity but higher selectivity and antioxidant activity.

When making comparisons between proteolytic enzymes in other plants (see Table 1), even though both papain and bromelain exhibit good results in meat tenderization, there are some clear benefits of using kiwi extract: selectivity and high content of antioxidants that make this option more preferable from the point of sensory and nutritional aspects.

In a comparative investigation, De Guzman et al. [13] noted that all three fruits were capable of softening meat tissue, but in comparison to other fruits, papaya exhibited the greatest effect. Selectivity of actinidin is an important factor because it allows better control of the process and reduces the chances of over-tenderization [10, 8]. However, as proved by Sedeeq and Saleh [4],

pineapple bromelain can be used without risks of over-tenderization at 10% concentration and 30-minute treatment.

On a more practical note, these findings indicate that the kiwi extract can be used as an ingredient in marinades for added-value chicken meat products. Further research might focus on the effect of various kiwi species, ways of cooking, as well as the potential risks of developing allergies due to the presence of actinidin, which was found to be one of the kiwi allergens [7]. In addition, it is desirable to compare the effects of extracts from kiwis and pineapples on the same meat type using the same methodology.

5. Conclusion

The usage of extract of the kiwi fruit at 10% concentration and marination period of 30 minutes led to the most successful meat qualities. This included increased tenderness, which was evidenced by 52% lower shear forces; reduced cooking losses, which were 46% lower; limited lipid oxidation due to 55% lower TBA values, and highest consumer acceptance. Results were either similar to the study conducted by Sedeeq and Saleh [4] (48% reduction in shear forces, 42% reduction in cooking loss and 39% reduction in TBA value with pineapple bromelain) or even better than theirs. Antioxidant capacity of the kiwi extract was also found to be significantly higher. Due to the fact that actinidin is selective proteinase, its use in meat tenderization process had some advantages compared to use of the others such as bromelain and papain. Despite that, both the extracts can be used for meat softening purposes under certain conditions.

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