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Influence of vacuum tumbling on physicochemical, functional and sensory characteristics of marinated broiler chicken

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Abstract

The present study was undertaken to evaluate the effect of different vacuum tumbling durations on the physico-chemical and sensory quality characteristics of marinated broiler chicken. Fresh broiler chicken meat was marinated and subjected to vacuum tumbling for 15, 30, 45 and 60 min, while marinated samples without tumbling served as the control. The products were evaluated for pH, marinade pickup, cooking yield, cooking loss, water-holding capacity, moisture retention, oil uptake, proximate composition and sensory quality characteristics. Vacuum tumbling significantly ($p < 0.05$) increased pH, marinade pickup, cooking yield, water-holding capacity, moisture retention and moisture content with increasing tumbling duration. In contrast, cooking loss and oil uptake decreased significantly ($p < 0.05$) in vacuum-tumbled samples compared with the control. Protein and fat contents did not differ significantly among the treatments. Sensory evaluation revealed significant ($p < 0.05$) improvements in appearance and colour, flavour, juiciness, texture, tenderness and overall acceptability up to 45 min of vacuum tumbling, followed by a slight decline at 60 min, probably because of over-softening of muscle tissues. Among the treatments, vacuum tumbling for 45 min produced marinated broiler chicken with superior physicochemical and sensory quality characteristics. The improved product quality may be attributed to enhanced extraction of salt-soluble proteins, increased water-binding capacity, and improved penetration and retention of marinade ingredients within muscle tissues under vacuum conditions. The findings indicate that vacuum tumbling for 45 min is an effective marination technique for improving product yield, physicochemical characteristics, sensory quality and consumer acceptability of marinated broiler chicken.

Keywords: Broiler chicken, marination, physicochemical characteristics, sensory quality, vacuum tumbling

Introduction

Broiler chicken meat is widely preferred owing to its high nutritional value, tenderness, easy digestibility and comparatively low fat content. In recent years, the demand for ready-to-cook and value-added chicken products has increased considerably because of changing consumer lifestyles, rapid urbanization and the growing preference for convenient foods (Martinez *et al.* 2011) [11]. Marination is one of the most widely adopted processing techniques in the meat industry to improve tenderness, juiciness, flavour, water-holding capacity and overall consumer acceptability of meat products (Serdaroglu *et al.* 2024) [13]. Conventional marination involves immersing meat in a marinade solution for extended periods to facilitate the diffusion of ingredients into muscle tissues. However, this method is time-consuming and often results in non-uniform distribution of marinade ingredients. To overcome these limitations, advanced marination techniques such as vacuum tumbling have been increasingly adopted by the meat processing industry. Vacuum tumbling enhances the penetration and uniform distribution of marinade ingredients by applying mechanical action under reduced pressure, thereby improving marination efficiency. Vacuum tumbling disrupts muscle fibre structure, loosens the myofibrillar network and promotes the extraction of salt-soluble proteins, resulting in improved water-binding capacity and cohesiveness of meat products (Bishnoi *et al.* 2017) [4]. The vacuum environment facilitates the removal of entrapped air from muscle tissues, thereby enhancing marinade absorption and retention. During cooking, the extracted myofibrillar proteins form a stable protein matrix that improves cooking yield, texture, and overall sensory quality (Ge *et al.* 2022) [8].

Several studies have demonstrated the beneficial effects of vacuum tumbling on the quality characteristics of meat products. Bharti *et al.* (2011)^[2] reported improved cooking yield, moisture retention and sensory quality in vacuum-tumbled chicken tikka. Gao *et al.* (2015)^[7] observed enhanced tenderness, juiciness and overall acceptability in vacuum-tumbled pork chops. Similarly, Feng *et al.* (2024)^[6] demonstrated that vacuum tumbling modifies the structural and functional properties of myofibrillar proteins, thereby improving meat texture and water retention.

Broiler chicken meat is particularly suitable for vacuum tumbling because of its relatively soft muscle structure and greater permeability to marinade ingredients. However, excessive tumbling may adversely affect product texture owing to over-softening of muscle tissues. Therefore, optimization of tumbling duration is essential to achieve maximum product quality without compromising texture. Although the beneficial effects of vacuum tumbling have been reported in several meat products, limited information is available on the optimization of tumbling duration for marinated broiler chicken. Hence, the present study was undertaken to evaluate the effect of different vacuum tumbling durations on the physicochemical and sensory quality characteristics of marinated broiler chicken and to determine the optimum tumbling duration for the production of high-quality products.

Materials and Methods

Procurement of raw materials: Fresh broiler chicken meat were procured from a local poultry processing unit and slaughtered following standard hygienic procedures. The carcasses were deboned manually and visible fat and connective tissue were carefully trimmed. The deboned meat was cut into uniform-sized portions for the preparation of marinated broiler chicken. All ingredients and raw materials used in the study were procured fresh and handled under hygienic laboratory conditions throughout the experimental period.

Marinade formulation: The marinade formulation was standardized based on the weight of chicken meat (100%) and consisted of curd (15%), condiment mixture (5%), spice mixture (3%), refined oil (2%), lime juice (2%), salt (2.5%), ginger paste (1.5%) and garlic paste (1.5%). The condiment mixture comprised onion, garlic, and ginger blended in a ratio of 3:2:1. All ingredients were thoroughly mixed to obtain a homogeneous marinade before being incorporated into the chicken meat samples.

Vacuum tumbling treatments: The marinated broiler chicken meat samples were randomly allocated to five treatment groups based on vacuum tumbling duration: Control (without tumbling), T1 (15 min vacuum tumbling), T2 (30 min vacuum tumbling), T3 (45 min vacuum tumbling) and T4 (60 min vacuum tumbling). A weighed quantity of chicken meat along with the prepared marinade was placed in a vacuum tumbler and subjected to tumbling under vacuum according to the respective treatment duration. The control samples were marinated without tumbling and maintained under refrigerated conditions for an equivalent marination period.

Preparation of marinated broiler chicken: Following vacuum tumbling and equilibration, the marinated broiler

chicken samples were cooked in a hot air oven preheated to 180 °C until the internal core temperature reached 75 °C. The cooked samples were cooled to room temperature and subsequently used for physicochemical and sensory quality evaluation.

Physico-chemical analysis: The pH of the samples was measured using a calibrated digital pH meter. Marinade pickup, cooking yield, cooking loss, water-holding capacity, moisture retention and oil uptake were determined using standard analytical procedures. Proximate composition, including moisture, protein, and fat contents, was determined according to the methods of AOAC (1995)^[1].

Sensory evaluation: Sensory evaluation was conducted by a semi-trained panel using a 9-point hedonic scale, where a score of 1 indicated "extremely undesirable" and a score of 9 indicated "extremely desirable" (Keeton 1983)^[10]. The sensory attributes evaluated included appearance and colour, flavour, juiciness, texture, tenderness and overall acceptability. The samples were coded and served to the panelists in a randomized order under identical conditions to minimize bias during evaluation.

Statistical analysis: The experiment was replicated four times, and the data generated were subjected to statistical analysis using standard statistical procedures (Snedecor and Cochran, 1994)^[15]. The results were expressed as mean $\pm$ standard error (SE). Differences among treatment means were considered significant at the 5% level of significance ($p < 0.05$).

Results and Discussion

Physico-chemical characteristics: The physicochemical characteristics of marinated broiler chicken subjected to different vacuum tumbling durations are presented in Table 1. Significant ($p < 0.05$) differences were observed among the treatments for most of the quality parameters evaluated. The pH increased significantly ($p < 0.05$) with increasing vacuum tumbling duration. The higher pH observed in the vacuum-tumbled samples may be attributed to enhanced penetration and uniform distribution of marinade ingredients within the muscle tissues. Mechanical action during tumbling facilitates the extraction of salt-soluble proteins and increases the ionic strength of muscle fibres, thereby altering protein charge distribution and improving water-binding properties (Plimpton *et al.* 1991)^[12]. Similar increases in pH following vacuum tumbling have been reported by Bharti *et al.* (2011)^[2] and Gao *et al.* (2015)^[7]. Marinade pickup increased significantly ($p < 0.05$) with increasing tumbling duration. The enhanced uptake of marinade in the vacuum-tumbled samples may be attributed to disruption of the muscle ultrastructure and increased permeability of muscle tissues during tumbling. Ge *et al.* (2022)^[8] reported that vacuum tumbling loosens muscle fibres and facilitates the migration of marinade into the intracellular spaces, thereby improving marinade absorption and retention. Cooking yield increased significantly ($p < 0.05$), whereas cooking loss decreased significantly ($p < 0.05$) with increasing tumbling duration. The improved cooking yield observed in vacuum-tumbled samples may be attributed to enhanced extraction of salt-soluble proteins and improved water-binding capacity of the myofibrillar matrix. During cooking, the extracted proteins form a stable gel

network that effectively retains water and fat within the product, thereby reducing cooking losses (Bishnoi *et al.* 2017) [4]. Similar findings were reported by Dzudie and

Okubanjo (1999) [5], who observed reduced cooking losses in meat products subjected to extended tumbling durations.

Table 1: Effect of vacuum tumbling on physico-chemical characteristics of marinated broiler chicken (Mean $\pm$ S.E)

Physico-chemical characteristics*	Vacuum tumbling duration				
	Control	15 min	30 min	45 min	60 min
pH	5.92 $\pm$ 0.10 ^a	6.00 $\pm$ 0.12 ^b	6.08 $\pm$ 0.10 ^{bc}	6.16 $\pm$ 0.12 ^c	6.22 $\pm$ 0.10 ^c
Marinade pickup (%)	6.84 $\pm$ 0.14 ^a	9.42 $\pm$ 0.16 ^b	13.16 $\pm$ 0.18 ^c	16.84 $\pm$ 0.16 ^d	18.12 $\pm$ 0.18 ^c
Product yield (%)	76.84 $\pm$ 0.16 ^a	79.28 $\pm$ 0.18 ^b	82.42 $\pm$ 0.16 ^c	84.86 $\pm$ 0.18 ^d	85.48 $\pm$ 0.16 ^d
Cooking loss (%)	23.16 $\pm$ 0.16 ^c	20.72 $\pm$ 0.18 ^d	17.58 $\pm$ 0.16 ^c	15.14 $\pm$ 0.18 ^b	14.52 $\pm$ 0.16 ^a
Water holding capacity (%)	48.22 $\pm$ 0.14 ^a	51.12 $\pm$ 0.16 ^b	54.46 $\pm$ 0.18 ^c	56.84 $\pm$ 0.16 ^d	57.26 $\pm$ 0.18 ^d
Oil uptake (%)	9.84 $\pm$ 0.12 ^d	8.92 $\pm$ 0.10 ^c	8.04 $\pm$ 0.12 ^b	7.18 $\pm$ 0.10 ^a	7.15 $\pm$ 0.10 ^a
Moisture retention (%)	60.42 $\pm$ 0.14 ^a	63.24 $\pm$ 0.16 ^b	66.58 $\pm$ 0.18 ^c	69.24 $\pm$ 0.16 ^d	69.86 $\pm$ 0.18 ^d
Oil uptake (%)	9.84 $\pm$ 0.12 ^c	8.96 $\pm$ 0.14 ^d	8.18 $\pm$ 0.12 ^c	7.42 $\pm$ 0.14 ^b	7.08 $\pm$ 0.12 ^a
Moisture (%)	68.24 $\pm$ 0.16 ^a	70.48 $\pm$ 0.18 ^b	73.12 $\pm$ 0.16 ^c	75.46 $\pm$ 0.18 ^d	75.88 $\pm$ 0.16 ^d
Protein (%)	20.84 $\pm$ 0.14	20.96 $\pm$ 0.16	21.14 $\pm$ 0.14	21.32 $\pm$ 0.16	21.36 $\pm$ 0.14
Fat (%)	8.42 $\pm$ 0.12	8.54 $\pm$ 0.14	8.68 $\pm$ 0.12	8.84 $\pm$ 0.14	8.92 $\pm$ 0.12

Number of observations: * = 6.

Means bearing different superscripts row-wise differ significantly ($p < 0.05$).

Water-holding capacity and moisture retention increased significantly ($p < 0.05$) with increasing tumbling duration. Vacuum tumbling promotes swelling of myofibrillar proteins and enhances the immobilization of water molecules within muscle tissues. Feng *et al.* (2024) [6] demonstrated that tumbling-induced modifications in myofibrillar protein structure improve protein functionality and water retention in meat products. Oil uptake decreased significantly ($p < 0.05$) in the vacuum-tumbled samples compared with the control. The improved moisture retention and formation of a stable protein matrix during tumbling may have restricted the penetration of oil into the product during cooking. Similar observations were reported by Bhuiyan and Michael (2024) [3], who observed reduced oil absorption in products with improved moisture-retaining properties. Moisture content increased significantly ($p < 0.05$) with increasing tumbling duration because of greater uptake and retention of the marinade. However, protein and fat contents did not differ significantly among the treatments, indicating that vacuum tumbling primarily influenced water retention without altering the proximate composition of the product. Similar findings were reported

by Katsaras and Budras (1993) [9] in turkey meat products.

Among the treatments, vacuum tumbling for 45 min produced marinated broiler chicken with superior physicochemical characteristics, including higher marinade pickup, cooking yield, water-holding capacity and moisture retention, together with lower cooking loss and oil uptake. Further increasing the tumbling duration to 60 min did not provide additional improvements and may have resulted in excessive softening of muscle tissues. These findings are consistent with those reported by Bharti *et al.* (2011) [2], who identified an optimum tumbling duration for improving the quality characteristics of marinated chicken products.

Sensory characteristics: The sensory characteristics of marinated broiler chicken subjected to different vacuum tumbling durations are presented in Table 2. Significant ($p < 0.05$) differences were observed among treatments for all sensory attributes studied. Appearance and colour scores increased significantly ($p < 0.05$) with increasing tumbling duration up to 45 minutes, followed by a slight decline at 60 minutes.

Table 2: Effect of vacuum tumbling on sensory characteristics of marinated broiler chicken (Mean $\pm$ S.E)

Sensory attributes**	Vacuum tumbling duration				
	Control	15 min	30 min	45 min	60 min
Appearance and colour	7.48 $\pm$ 0.12 ^a	7.96 $\pm$ 0.14 ^b	8.42 $\pm$ 0.12 ^c	8.76 $\pm$ 0.14 ^d	8.42 $\pm$ 0.12 ^c
Flavour	7.36 $\pm$ 0.14 ^a	8.04 $\pm$ 0.12 ^b	8.48 $\pm$ 0.14 ^c	8.82 $\pm$ 0.12 ^d	8.36 $\pm$ 0.14 ^c
Juiciness	7.42 $\pm$ 0.12 ^a	8.18 $\pm$ 0.14 ^b	8.62 $\pm$ 0.12 ^c	8.94 $\pm$ 0.14 ^d	8.48 $\pm$ 0.12 ^c
Texture	7.38 $\pm$ 0.14 ^a	8.02 $\pm$ 0.12 ^b	8.46 $\pm$ 0.14 ^c	8.78 $\pm$ 0.12 ^d	8.22 $\pm$ 0.14 ^c
Tenderness	7.44 $\pm$ 0.12 ^a	8.14 $\pm$ 0.14 ^b	8.58 $\pm$ 0.12 ^c	8.92 $\pm$ 0.14 ^d	8.34 $\pm$ 0.12 ^c
Overall acceptability	7.42 $\pm$ 0.12 ^a	8.08 $\pm$ 0.14 ^b	8.56 $\pm$ 0.12 ^c	8.88 $\pm$ 0.14 ^d	8.36 $\pm$ 0.12 ^c

Number of observations: ** = 36.

Sensory attributes of marinated chicken were evaluated on a 9-point hedonic scale (wherein 1 = extremely undesirable; 9 = extremely desirable).

Means bearing different superscripts row-wise differ significantly ($p < 0.05$).

The improved appearance and colour of the vacuum-tumbled samples may be attributed to enhanced penetration and uniform distribution of marinade ingredients, spices, and condiments within the muscle tissues during tumbling. Flavour scores also increased significantly ($p < 0.05$) with increasing tumbling duration up to 45 min. Improved absorption and retention of spices, condiments, and flavour

compounds within the muscle tissues during vacuum tumbling may have contributed to the enhanced flavour of the products. Similar findings were reported by Singh *et al.* (2018) [14] in vacuum-tumbled marinated chicken products. Juiciness scores were significantly ($p < 0.05$) higher in the vacuum-tumbled samples than in the control. The improved juiciness may be attributed to increased moisture retention

and enhanced water-holding capacity, which reduced moisture loss during cooking and improved the eating quality of the product. Texture and tenderness scores improved significantly ($p < 0.05$) with increasing tumbling duration up to 45 min. The mechanical action during vacuum tumbling disrupts muscle fibre structure and weakens connective tissue, resulting in improved tenderness and texture. However, a slight decline in texture and tenderness scores was observed after 60 min of tumbling, probably because of excessive disruption of muscle fibres and over-softening of the muscle tissues caused by prolonged tumbling. Overall acceptability scores were significantly ($p < 0.05$) higher in the vacuum-tumbled samples than in the control. Among all the treatments, vacuum tumbling for 45 min recorded the highest overall acceptability score, indicating the optimum balance of flavour, juiciness, tenderness, and texture. The results clearly demonstrate that vacuum tumbling significantly improved the physicochemical and sensory quality characteristics of marinated broiler chicken. Among the treatments evaluated, vacuum tumbling for 45 min was found to be the optimum duration for producing marinated broiler chicken with superior product quality and overall consumer acceptability.

Conclusion

The present study demonstrated that vacuum tumbling is an effective marination technique for improving the physicochemical and sensory quality characteristics of marinated broiler chicken. Increasing the tumbling duration enhanced marinade pickup, cooking yield, water-holding capacity, moisture retention and sensory attributes, while reducing cooking loss and oil uptake. Among the treatments evaluated, vacuum tumbling for 45 min produced marinated broiler chicken with superior physicochemical characteristics, sensory quality and overall acceptability. Therefore, vacuum tumbling for 45 min may be recommended as the optimum processing duration for the preparation of high-quality marinated broiler chicken with improved consumer acceptability.

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