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Effect of tumbling on processing of muscle foods: A review

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Abstract
Tumbling is a physical process that imparts mechanical action by lifting the meat to the highest point of rotation in a cylindrical drum and dropping the meat to the lower surface by gravity. Tumblers were initially designed in Europe for development of sectioned and formed meats. The process is being used in meat industry to improve the quality of tough meats and for faster distribution of curing ingredients. The process may be carried for short duration or long duration. Mostly vacuum tumbling is preferred. This paper evaluates the effect of tumbling on physicochemical, proximate and sensory quality of meat and meat products.

Keywords: tumbling, muscle foods, cylindrical drum

Introduction
With the changing scenario, there has been a rise in the demand for processed meat products. Recently the process of tumbling or fall massage has been used to improve the quality of tough meats such as pork and beef. This technology is also used for production of re-formed and re-structured meat. Tenderness and colour of meat products are two of the most important quality attributes affecting consumer satisfaction. Binding characteristics of muscle and water holding capacity effects the sensory characteristics of meat products. The muscular components responsible for these characteristics are the myofibrillar proteins which are extracted and solubilized to form exudate.

In the manufacture of cooked meat products, curing is widely complemented with tumbling in rotating drums, which is known to improve the meat-product properties [1]. In this process the kinetic energy of falling meat pieces is utilized to fracture the myofibrillar membrane structure, resulting in the extraction of salt soluble, heat- coagulable proteins. This increases the cohesiveness of meat pieces. Also the yield and tenderness increases. As the most severe kind of physico-mechanical treatment process, tumbling involves meat rotating, falling, and contacting with metal walls and paddles in a drum [2]. Tumbling is also favorable from an eating point of view, since it results in more tender and juicy meat [3]. Two major methods of tumbling treatment are continuous and intermittent tumbling in which the meat is tumbled for a period in each hour. The later process is the more effective but it lengthens the overall process time.

The functions of tumbling are to improve yield, increase tenderness and cohesiveness. It provides faster and more uniform ingredient distribution in the meat [4, 5]. According to Treharne [6] tumbling is defined as the massaging of meat surfaces. Tumbling has many beneficial effects, some of which are due to the formation of a protein exudates, this protein exudate acts as a sealer when the protein is denatured during thermal processing. Vartorella [7] and Krause[8] added that this exudate helps to hold juices during smoking and cooking, and results in increased yield, increased juiciness, and improved slicing characteristics of the finished product. Other benefits of tumbling include improved tenderness and more uniform cured meat color.

Tumbling also can be referred to as ‘brining–massaging’ which means that a controlled mechanical action is applied to the sample in addition to ‘static brining’. Studies carried out with pilot tumblers and reviewed by Siro *et al.* [9], Bombrun *et al*. [10, 11] and Daudin *et al*. [12] shows that tumbling improves water-holding capacity and texture compared to static brining and is necessary to produce a protein-containing exudate that determines piece-to-piece adhesion after cooking and thus end-product sliceability. It induces tissue structure softening and rupture, which causes an increase of brine sorption and protein extraction, and consequently an increment of cooking yield [13]. Tumbling treatments have been widely applied to pork. However, information about tumbling applied to beef is scarce and not quite appropriate referring to the incorporation of natural functional ingredients. Tumbling of meat has been described as a feasible technique to be used in the making process of dry-cured meat products [14]. Tumbling is generally done under vacuum to prevent protein and lipid oxidation. Moreover, combination of tumbling with certain additives has been reported to reduce lipid oxidation, including use of egg white on tumbling catfish [15] and the use of $CaCl_2$ and NaCl with tumbling has been effective in reducing oxidation in spent fowl meat [16]. Lawlis *et al*. [17] stated that there was a linear relationship between pre-rigor tumbling and cellular disruption and color distribution in ham roasts. In the ground meat system, the size of meat pieces arising from different particle reduction systems viz. grinding, chopping and flaking, influence the sensory attributes and tenderness.

When we talk about the tumblers, they are the horizontally or eccenterally mounted rotating drums. Some tumblers are hermatically sealed and equipped with vacuum pumps, which is considered to be better for distribution of curing ingredients but is equipment cost is significantly higher.

Effect of tumbling on meat and meat products.

1. Proximate composition

Dzudie and Okubanjo [19] found that the moisture and ash contents of the tumbled hams increased where as their protein content decreased as the tumbling time increased from 2 to 6 h. As the moisture content of the raw and cooked products increased with the increased in the tumbling time, there was a decrease in protein content of the corresponding products. Motycka and Betchel [20] observed a trend toward higher moisture and lower protein content of the hams as tumbling time increased from 4 to 24 h. This was probably due to increased migration of salt into the products. Fat content was not significantly affected ($p > 0.05$) by tumbling time. Ash content increases due to tumbling. The highest ash content found in the goat hams tumbled for the longest time was probably due to the high salt uptake during tumbling [18]. Such salts are detected in the ash [19]. At a constant fat level of nearly 8%, there was no significant difference (P>0.05) in the proximate composition and dimensional changes of low fat buffalo meat patties prepared at different grind sizes of 3mm, 4mm and 6 mm [20]. Tumbling resulted in significantly higher moisture content in the beef roasts [21].

2. Water holding capacity(WHC)

As the tumbling time increased for goat hams, there was an increase in WHC, salt content and residual nitrite. The increase in the tumbling time probably led to the increase in the amount of extractable salt soluble proteins which improved the WHC of the pre- and post-rigor meat, suggesting that the magnitude of muscle disruption was not similar in the pre- and post-rigor groups [18]. Whiting [22] reported that when myofibrillar protein was readily extractable, which gave the muscle a high WHC. Jairath *et al*. [23] found that vacuum tumbling resulted in significantly higher WHC. The WHC of minced raw meat emulsion increased with increase in the time of vacuum tumbling as the vacuum causes the product to absorb more marinade, which makes the product juicier and faster cooking.

3. pH

The pH of the meat and meat products is related to various quality attributes of meat. At a constant fat level of nearly 8%, there was no significant difference (P>0.05) in pH of low fat buffalo meat patties prepared at different grind sizes (3, 4, 6 mm) [20].

4. Cooking Yield/loss

Muller [24] reported higher product yield due to tumbling as compared to non-tumbled control. Increased tumbling time provides better chances for migration of curing solution in increased ionic strength and pH, which in turn enhance the product yield. Ghavimi *et al*. [25] observed insignificant difference between product yield from vacuum and aerobically tumbled meats. Yapar *et al*. [26] stated that with the increase in tumbling time, the emulsion stability increased which might be due to better stabilization of emulsion with time and thus improving the cooking yield. The exudates of myofibrillar protein seals moisture in the product as it coagulates on and immediately below the surface.

As the tumbling time increased for goat hams there was a decrease in cooking loss. The lower cooking loss associated with the longer tumbling time are explained by the higher moisture levels and higher WHC of the products [18]. At a constant fat level of nearly 8%, there was no significant difference (P>0.05) in the cooking yield of low fat buffalo meat patties prepared at different grind sizes (3, 4, 6 mm) [20]. Tumbled roast beef had a significantly higher cooking yield than the non-tumbled control. According to these results, tumbling did effectively function to increase cooking yield of precooked roast beef. Usually, phosphate with added salt increases ionic strength to extract salt soluble protein and makes the product much more uniform and with a higher cooking yield after tumbling [21]. Boles and Shand [27] found that the application of short tumbling prior to injection improved yield and tenderness of roast beef.

5. Shear force value

As the tumbling time (2 to 6 hrs) increased for goat hams there was a decrease in shear force values. The muscle fibers were disrupted by tumbling and shear force values of the hams decreased with the increase in tumbling time [18]. Chow *et al*. [28] showed that the instron measurement on pork ham tumbled for 9 h was significantly higher than that of the ham tumbled for 18 h. Shear force value increased significantly (P<0.05) with an increase in grind size [20].

Tumbled roast beef had significantly lower shear value than non-tumbled samples. The shear values were significantly increased (less tender) at day 7 compared with day 0. Basically, tumbled roast beef had relatively lower shear values compared to non-tumbled treatments and storage time increased toughness [21]. For shear values, samples with different a-tocopherol levels had the same tenderness. The non-tumbled precooked roast beef had significantly higher values (tougher) compared to those with tumbling.

6. Sensory properties

Tumbling the meat continuously for 2 to 6 h improved juiciness, tenderness and colour characteristics of the goat hams. The increase in the moisture content of the products and the disruption effect of tumbling on the muscle sarcolemma probably account for the increased juiciness and tenderness of the products. The significant improvement in the internal colour development of the hams was probably due to the effect of tumbling on the intensity and uniformity of diffusion of cure ingredients into the meat [18]. The sensory scores were significantly (P<0.05) higher for low fat buffalo meat patties prepared using 3 mm grind size as compared to those prepared at 4 and 6 mm grind sizes. Patties prepared at 3 mm grind size were rated significantly (P<0.05) higher in juiciness, texture and overall acceptability as compared to those prepared using 4 and 6 mm grind sizes. This could be due to the smaller particle size which provided increased binding in low-fat ground buffalo meat patties [20]. Rubberiness of low-fat ground beef patties was found to increase as the plate size increased to 2, 3 and 5 mm sizes [29]. Increasing tumbling time has been reported to improve protein binding and subsequent processing and quality traits [30].

Effect of tumbling on TBA value

For thiobarbituric acid reactive substances (TBARS) values, only sodium tripolyphosphate level and storage time had a significant two-way interaction. The TBARS value of tumbled roast beef with phosphates was the same as that of non-tumbled roast beef. It appears that sodium tripolyphosphate did not stop lipid oxidation, but it slowed its speed in precooked roast beef. The tumbling process promoted lipid oxidation when there was no antioxidant added. These results indicate that the tumbling process probably disrupts the cell membrane where the phospholipids are located and allows free radicals or catalysts an easy route to oxidize phospholipids, and may help oxygen penetrate inside the meat structure under non-vacuum tumbling. However, the benefit of the tumbling process allows increased distribution of phosphate to balance these disadvantages [21].

Effect of tumbling on microbial status

Tumbling did not influence the number of psychrotrophiles. There was no significant difference of mesophile for non-tumbled and tumbled roast beef at 0, 0.25, 0.4% phosphate level. At 0.5% phosphate, tumbled roast beef had significantly lower mesophile than non-tumbled samples. There was an insignificant difference between non-tumbled and tumbled samples at 0 and 0.25% phosphate. However, tumbled roast beef had significantly lower thermophile compared to non-tumbled samples at the 0.4 and 0.5% phosphate level [21]. According to Villalobos-Delgado *et al.* [31] there was no effect on microbial count for tumbling treatment and the interaction of tumbling and time.

Effect of salt on tumbling

Salt reacts synergistically with phosphates in the marinade and enhance WHC [32]. Salt extracts the salt soluble protein in meat. Presence of salt during tumbling reduces losses in cooking, but does not significantly affect the shear force value of the meat [33] at 2.5% NaCl, the WHC in cooked sausage was at maximum across the pH values with or without phosphate.

Conclusion

Tumbling results in a faster distribution of ingredients in cured and marinated meats. Use of tumbling technology results in a lesser intake of nitrite in curing brine to maintain the colour of cured meats. Tumbling also results in an increase in tenderness, juiciness and palatability of meat products. Desirable effects of tumbling improves with increase in tumbling time. But excessive tumbling may result in rubbery texture in meat products. So, careful selection of the optimum length of time is necessary. Tumbling proves to have a good potential for the manufacture of restructured meat products.

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