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Comparative Evaluation of Thermosonication and Conventional Cooking in Chicken Sausage

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Abstract
The popularity of chicken sausages in India is steadily increasing due to their convenience, versatility and nutritional benefits. Conventional thermal processing, although effective for ensuring microbial safety, can accelerate nutrient degradation and compromise product quality thermosonication, a hybrid technique that combined mile heat with ultrasonic cavitation that emerged as a promising alternative to address consumer demand for minimally processed foods. In this study, chicken sausages were subjected to temperatures from 62ºC - 70ºC at 2ºC intervals for durations of 25, 30, 35 and 40 minutes at 5 minutes interval. The process parameters were evaluated for manual cutting test, visual appearance and sensory analysis. Results indicated that thermosonication treatment produced sausages with improved texture, greater firmness, enhanced cohesiveness and more uniform visual appearance, while retaining moisture and structural integrity compared to conventional cooking. These findings highlight thermosonication as a promising and sustainable processing technology that is capable of enhancing the quality characteristics of meat products.

Keywords: Chicken sausage, Non-thermal technology, Thermosonication, Manual cutting test, Visual quality, Sensory analysis

Introduction
Meat is widely recognized as a valuable source of high - quality protein and essential nutrients such as vitamin B_{12}, iron, zinc and selenium that are vital for growth, tissue repair and overall health. Its appealing taste, aroma and texture makes preferred component of diets worldwide. Global meat consumption has increased significantly in recent decades, driven by population growth and rising incomes. With the world population projected to reach 9 billion by 2050, meat production will need to nearly double to meet protein demands and support global food security (Lee *et al*., 2020) [8].

Poultry meat with a moisture content of around 70.09% is a highly nutrient - dense food, providing approximately 18.59% protein, 6.0% fat and 0.80% ash. It is also rich in essential minerals such as iron and phosphorous, along with vitamins like niacin and riboflavin. Owing to high biological value and easy digestibility, poultry meat is a preferred choice among both young and elderly consumers (Sharma, 1999) [15].

The nutritional importance of chicken meat is well recognized as it is rich in mineral content that supports blood, cardiovascular and nervous system functions, while its low cholesterol and fat levels make it an ideal choice for individuals with vascular health concerns (EUP, 2019; Gordana *et al*., 2018) [4, 7]. Processed chicken products such as nuggets, patties, sausages and kebabs have become increasingly popular as they offer convenience, extended shelf life, improved flavour and texture. Their growing demand, especially in developing countries like India reflects changing lifestyles and rising poultry consumption (FAO, 2024).

Sausage is one of the most widely consumed meat products worldwide. The term refers to uncured, unheated products made from various meats such as beef, pork, chicken or fish with combined fat. These are typically chopped or emulsified and blended with region specific seasonings, spices, salt and colorants to enhance flavour and appearance (Pearson and Gillet). Commercially, sausages are typically processed using conventional heat treatments that ensure microbial safety and extend shelf life but often lead to the loss of heat - sensitive nutrients, colour, texture and flavour (Piyasena *et al*., 2003; Selby *et al*., 2006; Cichoski *et al*., 2015) [12, 13, 3].

To overcome these drawbacks, several novels non - thermal processing methods - such as pulsed electric fields, high pressure processing, ultrasonication, pulsed UV light and cold plasma are gaining attention for their ability to maintain product quality while ensuring microbial safety (Zell *et al*., 2010) [17]. Among these, ultrasound technology has emerged as an eco - friendly, non-toxic and versatile approach that used sound waves between 20 - 100 kHz to create cavitation, improving mixing, enzyme inactivation and microbial reduction (Awad *et al.,* 2012) [1]. A notable advancement is thermosonication that combined moderate heat (37-75 ºC) with ultrasound to effectively inactivate spoilage enzymes and pathogens, offering a promising alternative to conventional heat treatments.

Materials and methods

Chicken meat was deboned; thoroughly washed and excess water removed before processing. The meat was minced using MADO Patron mincer and dry ingredients such as salt, chili powder, refined wheat flour and chicken masala were incorporated. Wet ingredients such as oil, egg and ginger garlic paste were then blended into a uniform sausage emulsion. This emulsion was stuffed into artificial casings using a mechanical filler and rested a 15 - 18 ºC for 4 hours. The prepared sausages were stored at -18ºC until further use, subsequently sausages were processed by thermosonicator equipment at various thermosonication temperature (from 62ºC to 70 ºC at an interval of 2ºC), time (25 to 40 minutes at an interval of 5 minutes) outlined in Table 1, with slight procedural modifications Feiner.G (2006) [6].

Table 1: Thermosonication treatment of chicken sausages at varying temperatures and times.

Samples	Temperature (ºC)	Time (min)
S_1	62ºC	25
S_2	62ºC	30
S_3	62ºC	35
S_4	62ºC	40
S_5	64ºC	25
S_6	64ºC	30
S_7	64ºC	35
S_8	64ºC	40
S_9	66ºC	25
S_{10}	66ºC	30
S_{11}	66ºC	35
S_{12}	66ºC	40
S_{13}	68ºC	25
S_{14}	68ºC	30
S_{15}	68ºC	35
S_{16}	68ºC	40
S_{17}	70ºC	25
S_{18}	70ºC	30
S_{19}	70ºC	35
S_{20}	70ºC	40
S_0 (Control)	82ºC	20

Cooking is carried out until the core temperature reaches the optimized temperatures, then the samples were taken out of the thermosonicator bath and evaluated for manual cutting tests, visual quality and sensory analysis to assess the effectiveness of the cooking process.

Texture attributes - Manual cutting test

The manual cutting test was performed on both treated and control sausage samples by slicing them into cylindrical sections with a sharp stainless-steel knife in a single, uniform stroke to ensure consistency (Bourne, 2002) [2].

Visual quality

The visual quality of treated and control sausages was assessed immediately after cooking and cooling to room temperature. Each sample was evaluated for surface colour, uniformity, presence of cracks, fat separation and overall structural integrity (Meilgaard *et al.,* 2016) [9].

Sensory evaluation

Sensory evaluation of the thermosonicated chicken sausages was conducted using 9 - point hedonic scale (Shaik *et al.,* 2018) [14] by 15 panellists including faculty and students from College of Food and Dairy Technology, Koduveli, Chennai. Each sample was presented with a randomized code and evaluated at room temperature between 3:00 and 4:30 pm under day light conditions. Panellists were provided with water to rinse their palate between samples and the sensory attributes assessed included appearance, aroma, taste, tenderness and overall acceptability.

Statistical analysis

The test was repeated for each experimental condition and the results are presented as mean values. Statistical analysis was carried out using SPSS software (Version 25) to calculate averages and standard deviations, while Duncan's multiple range test was applied to determine significant differences at $p < 0.05$.

Result and discussion

Manul cutting tests and Visual quality of thermosonicated chicken sausages

Manual cutting test and visual quality of thermosonicated chicken sausage samples mentioned in Table 1 is shown in Plate 1. Manual cutting test and visual appearance are integral for evaluating chicken sausage quality, providing critical information on texture, structure and overall consumer appeal. When compared across different processing time and temperatures, sausages subjected to optimized conditions- temperatures (68ºC, 69ºC and 70ºC) exhibited improved textural attributes such as firmness, cohesiveness, well cooked with slice integrity, along with more uniform colour and reduced surface defects. In contrast, sausages processed at lower temperatures (< 68ºC) for shorter times often showed weaker structural integrity, lower firmness, under cooked and less visually appealing slice (Shin *et al*., 2022; Pena- Saldarriaga *et al.,* 2020) [16, 11].

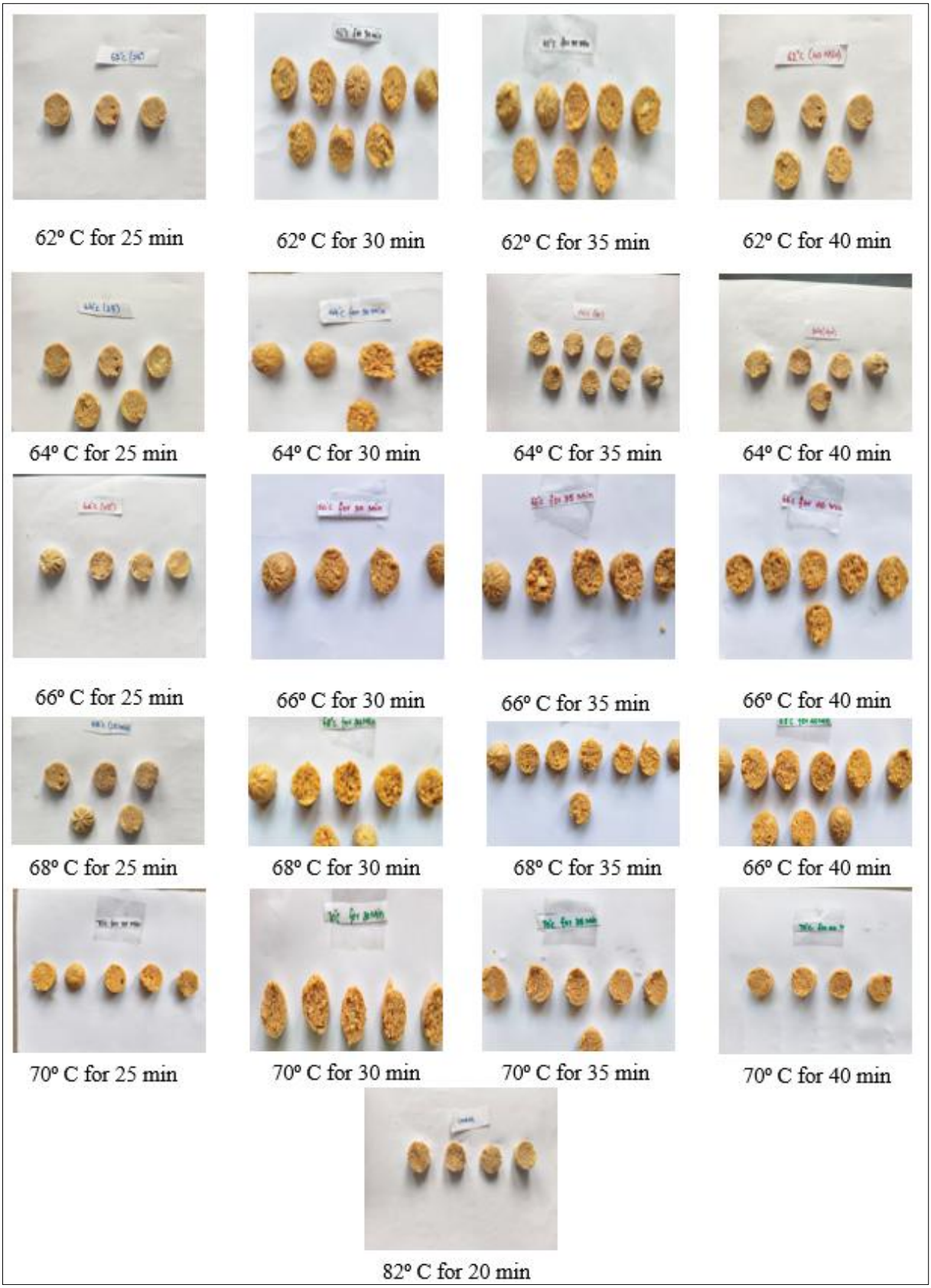

Plate 1: Manual cutting test and visual quality test for thermosonicated chicken sausages at different temperature and time

Sensory analysis

Sensory evaluation of chicken sausages subjected to different thermosonication temperatures and time combinations revealed significant differences ($p < 0.01$) in appearance, aroma, taste, tenderness and overall acceptability. Treatments up to S14 exhibited moderate scores, whereas treatments from S15 onwards showed marked improvements in all sensory attributes. In particular, S15 to S20 demonstrated substantial enhancement in appearance (6.66±0.12 to 8.93±0.06), taste (6.86±0.16 to 9.00±0.00) and tenderness (7.13±0.09 to 8.93±0.06), reflecting better juiciness and textural quality. Overall acceptability rose significantly from S15 (6.91±0.06) to S20 (8.95±0.03), indicating that increased temperature and time

combinations -in thermosonication produced more desirable sensory profiles. These findings align with previous research suggesting that ultrasound - assisted thermal processing enhances protein functionality, improves water retention and leads to a more stable gel matrix, thereby by improving tenderness and flavour perception (Shin *et al*., 2022; Pena - Saldarriaga *et al*., 2020) [16, 11]. The higher appearance scores from S15 onward may be linked to improved pigment stability and minimized cooking loss due to the synergistic effects of heat and acoustic cavitation. Additionally, the enhanced taste and aroma are likely a result of better flavour compound retention, as ultrasound - assisted processing minimizes nutrient degradation and preserves volatile compounds. Overall, the results confirm that thermosonication treatments from S15 onward offer the most favourable balance between appearance, aroma, taste, tenderness and overall consumer acceptability, highlighting its potential as superior alternative to conventional thermal processing in chicken sausage production.

Table 2: Sensory evaluation of chicken sausages at various thermosonication temperature and time combination shown in Table 1.

Parameters / Samples	Appearance	Aroma	Taste	Tenderness	Overall acceptability
S_1	5.00±0.000[a]	5.00±0.000 [a]	5.00±0.000 [a]	8.93±0.000 [a]	5.00±0.000[a]
S_2	5.00±0.000 [a]	5.00±0.000 [a]	5.00±0.000 [a]	5.00±0.000 [a]	5.00±0.000 [a]
S_3	5.00±0.000 [a]	5.00±0.000 [a]	5.00±0.000 [a]	5.00±0.000 [a]	5.00±0.000 [a]
S_4	5.00±0.000 [a]	5.00±0.000 [a]	5.00±0.000 [a]	5.00±0.000 [a]	5.00±0.000 [a]
S_5	5.00±0.053 [a]	5.20±0.065 [a]	5.167±0.063 [a]	5.50±0.000 [b]	5.24±0.014 [b]
S_6	5.00±.0.053 [a]	5.20±0.065 [a]	5.167±0.063 [a]	5.50±0.000 [b]	5.24±0.014 [b]
S_7	5.00±.0.053 [a]	5.20±0.065 [a]	5.167±0.063 [a]	5.50±0.000 [b]	5.24±0.014 [b]
S_8	5.00±0.503 [a]	5.20±0.065 [a]	5.167±0.063 [a]	5.50±0.000 [b]	5.24±0.014 [b]
S_9	6.00±0.000 [b]	6.00±0.000 [b]	6.00±0.000 [b]	6.00±0.000 [c]	6.00±0.000 [c]
S_{10}	6.00±0.000 [b]	6.06±0.045 [b]	6.00±0.000 [b]	6.10±0.053 [c]	6.04±0.019 [c]
S_{11}	6.00±0.000 [b]	6.33±0.126 [c]	6.00±0.000 [b]	6.33±0.126 [d]	6.16±0.062[d]
S_{12}	6.06±0.045 [b]	6.06±0.045 [b]	6.16±0.063 [b]	6.50±0.000 [d]	6.20±0.026 [d]
S_{13}	6.26±0.118 [c]	6.20±0.106[bc]	6.60±0.130 [c]	6.80±0.106[e]	6.46±0.068[e]
S_{14}	6.26±0.118 [c]	6.20±0.106[bc]	6.60±0.130 [c]	6.80±0.106 [e]	6.46±0.068 [e]
S_{15}	6.66±0.126 [d]	7.00±0.000[d]	6.86±0.165[d]	7.13±0.090[f]	6.91±0.062[f]
S_{16}	7.73±0.118 [e]	7.73±0.118 [e]	7.73±0.118[e]	7.73±0.118[g]	7.73±0.118 [g]
S_{17}	8.93±0.006 [f]	8.93±0.066[f]	9.00±0.000[f]	8.93±0.066[h]	8.95±0.036 [h]
S_{18}	8.93±0.006 [f]	8.93±0.066 [f]	9.00±0.000 [f]	8.93±0.066 [h]	8.95±0.036 [h]
S_{19}	8.93±0.006 [f]	8.93±0.066 [f]	9.00±0.000 [f]	8.93±0.066 [h]	8.95±0.036 [h]
S_{20}	8.93±0.006 [f]	8.93±0.066 [f]	9.00±0.000 [f]	8.93±0.066 [h]	8.95±0.036 [h]
S_0 (Control)	9.00±0.000 [f]	9.00±0.000 [f]	9.00±0.000 [f]	8.80±0.106 [h]	8.95±0.026 [h]
F Value	582.068**	552.545**	548.534**	496.160**	1275.723**

@Average of 15 trials; Non-significant - $P>0.05$; *Significant - $0.01<P\leq0.05$; **Highly significant - $P\leq0.01$

[a]Different superscripts indicate there are significant differences between values in the same row according to Duncan's multiple range test at $p<0.05$.

Conclusion

Manual cutting test, visual appearance and sensory analysis assessments confirms that thermosonication is a superior method for cooking chicken sausages compared to conventional cooking. By optimizing time and temperature, thermosonication produced sausages with improved texture, greater firmness, enhanced cohesiveness and more uniform visual appearance, while retaining moisture and structural integrity. In contrast, conventional cooking at fixed temperatures often resulted in higher cooking loss, less uniform texture and lower visual appeal. These results indicate that thermosonication provides a controlled processing environment that enhances both the quality and consumer acceptability of chicken sausages, making it a more effective cooking method than traditional techniques.

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