Impact of processing temperature and duration on physicochemical attributes of thermosonicated chicken sausage

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Abstract
The demand for chicken sausages in India is rising owing to their convenience, versatility, and favourable nutritional profile. Conventional thermal processing is for microbial safety but accelerates nutrient degradation and adversely impacts product quality. In response to consumer preference for minimally processed foods, thermosonication is a hybrid non thermal technology combining mild heat and ultrasonic cavitation that offers promising alternative. In this study the chicken sausages are subjected to temperatures between 61ºC to 70ºC for durations of 25, 30, 35, and 40 minutes. The process parameters were evaluated for their effects on cooking loss, product yield and pH. Results indicated that thermosonication treatments significantly reduced cooking loss and enhanced product yield compared to conventional cooking methods. These findings underscore the potential of thermosonication as an efficient and sustainable processing technique for improving the quality attributes of meat products.

Keywords: Chicken sausage, non thermal technology, thermosonication, cooking loss, product yield

1. Introduction
Meat has consistently been the best source of protein. A large portion of the global population consumes frequently due to its enticing flavour and taste in addition to nutritional qualities. Along with micronutrients like niacin, vitamin b12, iron, zinc, selenium and amino acids that are necessary for human health. It also has an impressive amount of fat and carbohydrates that serve as an energy source [1, 2].
The moisture content of poultry meat (70.09%) makes it a very nutrient dense food, protein (18.59%), ash (0.80%) and fat (6.0%). Minerals like iron and phosphorous, vitamins like niacin and riboflavin are abundant in poultry meat. It is a favourite food of both young people and elder due to its high biological value and ease of digestion [3].
Around the world, sausage is one of the most consumed foods [4] explained that fresh sausages are uncured and unheated meat products prepared from pork, beef, chicken, fish and fat with textures ranging from coarse to finely emulsified depending on local traditions.
Meat becomes more palatable and easier to digest when it is cooked. A cooking method produces high quality meat product with pleasing texture and flavour is chosen by customers.
For cooking of sausages, traditional cooking temperatures greater than 80ºC have been utilized. The temperature and time at which meat is cooked affects its physical properties and overall quality. Meat's unique proteins become denatured when cooked altering the textures structural integrity of the meat.
Despite the fact some of these procedures (like resistive and adiabatic heating during high pressure processing and pulsed electric field respectively) generate heat due to internal energy generation. They are termed non thermal as they control microorganisms without high temperatures, thus preserving the food flavour, colour and nutritional quality.
Thermsonication uses heat and ultrasound shown to be more effective method of inactivating microorganisms than either method by itself. Ultrasound treatment caused microbial

inactivation primarily due to generation of acoustic cavitation causing thinning of cell membranes, loss of selectivity and increased membrane permeability. During the cooling phase, confined heating and singlet electron transfer contributes to inactivation process [5].

Sausage was processed by using microwave and thermosonication methods [6]. Prototype sausage was heated at 80ºC for varying lengths of time (10, 20, 30, and 40 minutes) using the ultrasonic bath set to 40kHz and a microwave with 400, 600 and 800 W of power. This was done contrast to the traditional method of heating (75ºC for 15 minutes). The effects of microwaves and thermosonication on chemical, physical and microbiological characteristics of sausage samples as well as degree of consumer preference were examined using randomized design. As, a result the prototype sausage shelf life was increased and the meat quality was preserved under ideal thermosonication conditions of 80 ºC for 20 minutes.

Commercial chicken sausage frankfurters prepared using ohmic heating at 45, 50 and 55 V and compared their colour, texture, moisture content and water activity with non-heated samples [7]. They reported that water activity decreased significantly at 50 V while, the hardness and shear force at this level were comparable to non-heated sausages.

German and gourmet sausages containing 40% and 65% raw meat irradiated at doses 2, 4, 6 and 8 kGy were examined and found higher doses (8 kGy) reduced colour, taste and odour scores, while lower doses (2 - 4 kGy) better preserved sensory quality. Overall, lower levels of gamma irradiation were considered effective in reducing residual nitrite and enhancing shelf life of sausage.

2. Materials and Methods

The chicken meat was deboned, cleaned and washed thoroughly; excess water was removed as part of the preparation carried out. The meat was minced using an MADO Patron mincer, after salt, chilli powder, maida and chicken masala were added. Using a bowl chopper oil, egg and ginger garlic paste was blended into the mixture to form uniform sausage emulsion. This emulsion was filled into artificial casings with a mechanical filler and left to rest at 15 - 18ºC for 4 hours. The sausages were then stored at -18ºC until further processing. Cooking was performed in a thermosonicator by using 5 liters water, varying temperature and time as per Table 1. Following the procedure prescribed with slight modifications [8].

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

Samples	Temperature (ºC)	Time (min)
T_1	61 ºC	25
T_2	62 ºC	25
T_3	63 ºC	25
T_4	64 ºC	25
T_5	65 ºC	25
T_6	66 ºC	25
T_7	67 ºC	25
T_8	68 ºC	25
T_9	69 ºC	25
T_{10}	70 ºC	25
T_{11}	61 ºC	30
T_{12}	62 ºC	30
T_{13}	63 ºC	30
T_{14}	64 ºC	30
T_{15}	65 ºC	30
T_{16}	66 ºC	30
T_{17}	67 ºC	30
T_{18}	68 ºC	30
T_{19}	69 ºC	30
T_{20}	70 ºC	30
T_{21}	61 ºC	35
T_{22}	62 ºC	35
T_{23}	63 ºC	35
T_{24}	64 ºC	35
T_{25}	65 ºC	35
T_{26}	66 ºC	35
T_{27}	67 ºC	35
T_{28}	68 ºC	35
T_{29}	69 ºC	35
T_{30}	70 ºC	35
T_{31}	61 ºC	40
T_{32}	62 ºC	40
T_{33}	63 ºC	40
T_{34}	64 ºC	40
T_{35}	65 ºC	40
T_{36}	66 ºC	40
T_{37}	67 ºC	40
T_{38}	68 ºC	40
T_{39}	69 ºC	40
T_{40}	70 ºC	40
T_{41}	Control (82 ºC)	20

After cooking the samples were removed from thermosonicator bath. Cooking loss, product yield and pH were determined.

2.1 Cooking loss
Weighing the chicken sausage before and after cooking is the most common method. The difference between the raw weight and cooked weight, which is frequently given as a percentage, is then used to compute cooking loss [9].

$$Cooking\ loss = \frac{Wt\ before\ cooking - Wt\ after\ cooking}{Wt\ before\ cooking} \times 100$$

2.2 Product yield
Product yield was determined by measuring the weight of the sample before and after cooking using the following equation and the results were reported as percentages [10, 11].

$$Cooking\ yield\ \% = \frac{Wt\ after\ cooking}{Wt\ before\ cooking} \times 100$$

2.3 pH
The pH was determined using a digital pH meter [12].

3. Statistical analysis
All tests were performed at least three times for each experimental condition and mean values were reported, statistical analysis was performed by using the Statistical Package for the Social Sciences (version 25) to calculate the average and standard deviation. When Duncan's multiple range test method was used, the significance test ($p<0.005$) was carried out through multiple tests.

4. Results and discussion
4.1 Cooking loss
The cooking loss values of thermosonicated chicken sausages processed under varying time and temperature condition are presented in Table 2. Specifically, higher cooking temperatures or longer processing times resulted in increased cooking loss. This increased progressively with rising processing temperature and extended treatment time. The lowest cooking loss (0.354±0.002%) was observed at 61ºC for 25 minutes, while the highest value (4.470±.014%) occurred at 70ºC for 40 minutes. This trend can be attributed to the greater denaturation and shrinkage of myofibrillar proteins at higher temperatures, which results in reduced water holding capacity and increased exudation of moisture and soluble nutrients during cooking. Prolonged exposure to heat promotes connective tissue contraction, further enhancing fluid loss from the meat matrix. Cooking loss ($P \leq 0.005$) is highly significant. Cooking loss was significantly increased with increasing temperature and time.

4.2 Product yield
The result of product yield of thermosonicated chicken sausage and control was summarized in Table 2. With different time and temperature. Product yield of thermosonicated chicken sausages was significantly reduced with processing temperature and time. Higher yields (99.6%) were obtained at lower temperatures (61 - 64 ºC) and shorter time duration (25 - 30 minutes) indicating better moisture retention. As both temperature and time increased, product yield decreased progressively reaching a minimum of 93.53% at 70 ºC for 40 minutes. This reduction is attributed to enhanced protein denaturation and moisture loss under prolonged thermal and ultrasonic treatment.

The ultrasound assisted processing temperatures exceeding 65 ºC significantly decreases product yield in chicken sausages due to intensified protein unfolding and fibre contraction [13]. Similarly, The prolonged ultrasound treatment combined with heat increases drip loss in pork batters confirming the role of treatment duration and temperature in compromising product yield.

Ultrasound accelerates protein gelation but excessive exposure causes protein aggregation and shrinkage impairing the meat matrix's ability to retain water and fat [14]. Whereas, processing intensity is critical to optimize microbial safety without detrimentally affecting product yield [15].

4.3 pH
The result of pH of thermosonicated chicken sausage is summarized in Table 2. The pH values of thermosonicated chicken sausages ranged from 6.12 to 6.67 across different processing times and temperatures. The pH values are highly significant ($P \leq 0.005$) was observed in pH variation with respect to time and temperature indicating that thermosonication under the studied conditions did not significantly alter the overall acidity or alkalinity of the product.

Slight fluctuations in pH could be attributed to protein denaturation and the release of acidic or basic groups during heat and ultrasound treatment can modify the muscle matrix microenvironment [16]. Importantly pH values remained within the typical range for fresh meat products (generally 5.8 - 6.8) suggesting that processing did not induce spoilage or undesirable chemical changes [17].

Table 2: Effect of Thermosonication Temperature and Time on Cooking loss, Product yield and pH of Chicken Sausages.

Samples	Temp (ºC)	Time (min)	Cooking loss (%)	Product yield (%)	pH
T_1	61 ºC	25	0.354±0.002	99.646±0.002x	6.670±.039mn
T_2	62 ºC	25	0.368±0.002	99.632±0.002x	6.300±.043def
T_3	63 ºC	25	0.428±0.001	99.571±0.003vwx	6.540±.015jk
T_4	64 ºC	25	0.434±0.0006	99.565±0.001vwx	6.660±.012mn
T_5	65 ºC	25	0.666±0.0008	99.334±0.002tu	6.250±.014bcd
T_6	66 ºC	25	0.733±0.001	99.267±0.001st	6.260±.009bcde
T_7	67 ºC	25	0.818±0.036	99.217±0.001s	6.350±.011fg
T_8	68 ºC	25	1.065±0.001	98.934±0.001p	6.590±.018l
T_9	69 ºC	25	1.374±0.005	98.626±0.001m	6.450±.010h
T_{10}	70 ºC	25	1.859±0.002	98.141±0.002l	6.670±.006mn
T_{11}	61 ºC	30	0.389±0.002	99.6110±0.002wx	6.210±.013b
T_{12}	62 ºC	30	0.462±0.001	99.538±0.002vw	6.330±.008fg
T_{13}	63 ºC	30	0.474±0.001	99.526±0.002vw	6.380±.017g

T_{14}	64 ºC	30	0.722±0.000	99.278±0.002st	6.250±.013bcd
T_{15}	65 ºC	30	0.740±0.001	99.259±0.005st	6.240±.012bc
T_{16}	66 ºC	30	0.787±0.002	99.213±0.002s	6.240±.012bc
T_{17}	67 ºC	30	1.100±0.006	98.900±0.177op	6.760±.0220
T_{18}	68 ºC	30	1.950±0.009	98.050±0.012k	6.330±.012fg
T_{19}	69 ºC	30	2.010±0.023	97.990±0.022 k	6.350±.010fg
T_{20}	70 ºC	30	2.606±0.000	97.393±0.005gh	6.620±.0196lm
T_{21}	61 ºC	35	0.507±.001	99.493±0.002v	6.430±.012h
T_{22}	62 ºC	35	0.607±.001	99.393±0.002u	6.470±.014hi
T_{23}	63 ºC	35	0.748±.001	99.252±0.00st	6.320±.010f
T_{24}	64 ºC	35	0.783±.001	99.217±0.003s	6.260±.011bcde
T_{25}	65 ºC	35	0.811±.001	99.189±0.002rs	6.680±.010n
T_{26}	66 ºC	35	1.170±.010	98.830±0.016no	6.350±.011fg
T_{27}	67 ºC	35	2.103±.001	97.897±0.001 j	6.660±.012mn
T_{28}	68 ºC	35	2.562±.001	97.438±0.001 hi	6.510±.017ij
T_{29}	69 ºC	35	2.954±.0009	97.046±0.001 f	6.660±.012mn
T_{30}	70 ºC	35	3.117±.002	96.883±0.002 e	6.330±.008fg
T_{31}	61 ºC	40	0.614±.002	99.386±0.001u	6.270±.014cde
T_{32}	62 ºC	40	0.787±.001	99.213±0.002s	6.470±.010hi
T_{33}	63 ºC	40	0.880±.011	99.120±0.012qr	6.310±.012ef
T_{34}	64 ºC	40	0.946±.001	99.054±0.003q	6.510±.017 ij
T_{35}	65 ºC	40	1.201±.001	98.799±0.002n	6.580±.009kl
T_{36}	66 ºC	40	2.484±.001	97.516±0.002 i	6.430±.008h
T_{37}	67 ºC	40	2.650±.011	97.350±0.009 g	6.620±.014lm
T_{38}	68 ºC	40	3.643±.001	96.357±0.001 d	6.330±.008fg
T_{39}	69 ºC	40	3.768±.001	96.232±0.001 c	6.120±.008a
T_{40}	70 ºC	40	4.470±.014	95.530±0.008 b	6.380±.019g
T_{41}	Control (82 ºC)	20	5.520±.014	94.480±0.015 a	6.590±.0200l
F value			21898.625**	1947.044**	104.668**

5. Conclusion
The application of thermosonication as an alternative cooking method for chicken sausage significantly reduces cooking loss while enhancing product yield. This advanced technique effectively preserves moisture and minimizes the loss of fats and nutrients, thereby improving the overall quality and nutritional value of the final product. Incorporating such innovative cooking technologies in sausage production not only offers economic advantages through higher yield but also elevates consumer satisfaction by delivering a superior product. These findings highlight the potential of modern processing methods to optimize meat product quality and efficiency in the food industry.

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Conflict of Interest
Not available.

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