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Research Article

Thawing Effects on the Quality of Animal and Plant-Based Sausage Patties

Dakota Cook, Julie K Northcutt and Paul Dawson*

Department of Food, Nutrition, and Packaging Science, Clemson University, Clemson, South Carolina, USA

Abstract

Maintaining sausage analogue quality during thawing and storage is important for consumer satisfaction. Following new trends and prevalence of plant-based meats and a flexitarian diet, this experiment was conducted to evaluate the effects of thawing methods on meat and meat analogue quality. Jimmy Dean Original Sausage Patties Made with Pork & Turkey, Morningstar Veggie Original Patties and Beyond Sausage Original Patties were purchased pre-frozen and subsequently thawed using one of three methods: 1. thawed at 4°C for 24 hours, 2. thawed at room temperature (22°C±2°C) for 4 hours and 3. thawed in the microwave for 30-35 seconds. The quality of meat and meat analogues was evaluated by measuring thaw loss percentage, color, water activity, pH, sensory scoring, GC-headspace volatiles, TBARS values, Texture Profile Analysis (TPA) and cooking loss. The most striking difference in thawing effects was a higher thaw loss in microwaved samples compared to the other methods (p≤0.05). Despite the impact of methodology on samples, patty types were the largest indicator of quality with Morningstar patties viewed as the highest quality reflected by low moisture loss and high scores in sensory trials.

Keywords: Animal based sausage; Plant-based sausage; Thawing effects

Introduction

Consumers moving to a flexitarian diet are seeking alternatives to their favorite meats for their perceived health and environmental impacts. Ideal meat analogues have similar quality characteristics of animal-based products, from sensory components that include texture and flavor to nutritional attributes such as fat and protein content.

Meat and meat analogue products are often frozen to extend shelf life, which requires thawing prior to cooking. Thawing is an

***Corresponding author:** Paul Dawson, Department of Food, Nutrition, and Packaging Science, Clemson University, Clemson, South Carolina, USA, Tel No: +1 8646561138; E-mail: pdawson@clemson.edu

important step to ensure that food is cooked to a safe internal temperature. Thawing rate can affect microbial growth, chemical deterioration and loss of water [1]. Freezing disturbs the homeostasis of food as the concentration of other solutes (proteins, carbohydrates, lipids, vitamins and minerals) increase in the unfrozen liquid phase and followed by thawing the ice crystal damage to food structure can result in purge and damage to food strucutre1. Research on thawing methods and quality of plant-based meat analogues is lacking; however, studies on traditional sausage patties suggest they can remain refrigerated for approximately 7 days in 4.4°C temperatures [2]. Optimal thawing is essential to generate the best possible food quality and high sensory acceptability [1].

Joo et al. [3], divided meat quality into three components that includes reliance, appearance and eating quality traits. Consumers typically rely on appearance quality traits [3], when purchasing items since a visual assessment if often the only way to assess quality at the point of purchase. Consumers decide on whether or not to purchase an item again based upon the eating quality traits [3,4]. Appearance, such as color, results from visual inspection to determine perceived freshness of meat whereas eating quality refers to how the product is perceived in terms of flavor and texture [3,4]. Most studies are conducted with these characteristics in mind to thoroughly investigate quality attributes and changes.
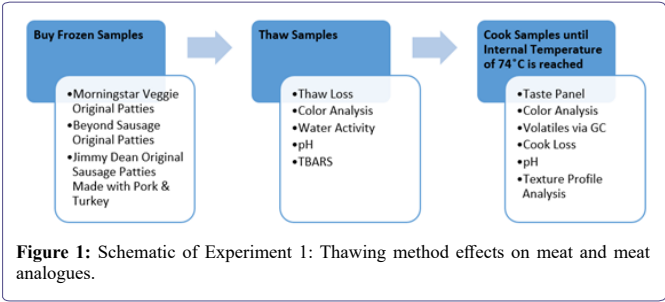
The overall objective of this study was to determine the effect of thawing method (ambient air/room temperature, refrigerator, or microwave) on the quality of meat and meat analogue sausage patties. Quality after thawing was evaluated using thaw loss, color analysis, water activity, pH, TBARS, headspace Gas Chromatograph (GC) volatiles, texture analysis, cook loss and taste panel.

Materials and Methods

Experiment 1: Effects of Thawing Method

Experiment 1 was replicated three different times using different sausage samples. The effects of different thawing methods on meat and meat analogues were evaluated using commercially available products purchased from a local grocery store. The meat and meat analogue samples that were tested using different tawing methods included: 1. Jimmy Dean™ Original Sausage Patties Made with Pork & Turkey; 2. Morning Star Farms™ Original Sausage Patties; and 3. Beyond™ Breakfast Sausage Original Plant-Bases Patties. The three thawing methods that were evaluated on each of the aforementioned products were: thawing sausage patties at 4°C for 24 hours, thawing patties at room temperature (22°C±2°C) for 4 hours and thawing patties in the microwave for 30-35 seconds. All products were analyzed immediately after thawing and after cooking. Figure 1 shows the outline of methods used for the thawing phase of the experiment.

During each of three replications, two patties from each type of product were removed from frozen storage and randomly allocated to one of the three types of thawing method. Frozen patties were weighed (Mettler Toledo Balance PB3002 scale. Columbus, OH) before thawing and again after thawing to record changes in weight.

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Figure 1: Schematic of Experiment 1: Thawing method effects on meat and meat analogues.

Each of the sausage types were subjected to one of three thawing methods. 1. Overnight thawing: samples placed directly in labeled Ziploc™ Brand Gallon Freezer Bags then held under refrigeration (4°C±2°C) for 24 hours. 2. Room temperature thawing: Samples thawed at room temperature were held for 4 hours at 20°C±2°C before being placed in the refrigerator at 4°C overnight. 3. Microwave thawing: The patties for the microwave thawing method were placed in a -18°C freezer overnight. The next day the patties designated to microwave thawing were thawed in a Magic chef microwave oven (St. Louis, MO) at 700 W for 30-35 seconds until thawed as decided visually and texturally during preliminary work. Beyond and Jimmy Dean sausage took 30 seconds while Morningstar sausage took 35 seconds to completely thaw. The samples previously weighed were blotted and weighed once again to determine thaw loss. Thaw loss was calculated as a percentage of the frozen weight as shown below:

$$\text{Thaw Loss (\%)} = \frac{\text{weight of frozen samples (g)} - \text{weight of thawed sample (g)}}{\text{weight of frozen samples (g)}} \times 100$$

Using the same sample, color measurements were recorded using a Minolta CR-400 Chroma Meter handheld colorimeter (Ramsey, NJ) that measured L* (lightness), a* (redness), and b* (yellowness) values at five locations. Before taking color measurements, the colorimeter was calibrated using a standard white tile (L*=56.95, a*=-21.94, b*=10.06). Samples were blotted before the color was measured and the colorimeter's lens was cleaned between each sample using a Kimwipe and ethanol spray. Hue and chroma were calculated using the following equations.

$$\text{Chroma} = \sqrt{a^2 + b^2}$$

$$\text{Hue} = \tan^{-1}\left(\frac{b}{a}\right)$$

Water activity, pH and Thiobarbituric Acid Reactive Substances (TBARS) were analyzed in duplicate using random samples from the remaining patties. Water activity was determined using two Rotronic Water Activity Meters (Rotronic, Zurich, Switzerland) that were connected to individual circulating water baths that maintained the sample chamber at 25°C. Samples were placed in the chamber for a minimum of 30 minutes to equilibrate before water activity readings were recorded. The pH was determined on a homogenized sample that was prepared by weighing approximately 10grams of a sausage patty into a dual range blender (Osterizer Pulse matic, Milwaukee, WI) containing 100ml of distilled water. This mixture was then homogenized on the high setting in the Osterizer Pulse Matic on the blend setting for 1 minute. The pH of the blended sample was determined using a Thermo Orion 420A pH meter (Waltham, MA).

For the TBARS assay, 2.5grams of sausage was homogenized with 10 ml deionized water for 20 seconds using a homogenizer (Osterizer Pulsematic, Milwaukee, WI). The solution was then placed in a 15ml

conical-bottom disposable plastic test tube and 3ml of Thiobarbituric Acid/Trichloroacetic Acid (TBA/TCA) solution was added. Samples were vortexed for a minute then heated in a 90°C water bath for 15 minutes. After 15 minutes, samples were cooled to room temperature then centrifuged in Eppendorf Centrifuge 5804R for 10 minutes at speed of 14000 x g and temperature at 22°C (Jo and Ahn) [5]. The supernatant was filtered using 0.45µm GHP Membrane Acrodisc (Pall Corporation, USA). Two ml of the filtered liquid was placed in another tube with 4ml of Thiobarbituric Acid (TBA) which is subsequently placed in a 96-well microplate in triplicates using 0.25ml. Absorbance is then read in a SpectraMax iD3 at 532nm and expressed as mg malondialdehyde/kg sample.

All remaining samples were cooked in a convection oven at 177°C for 8-9 minutes and flipped after 4 minutes in the oven until the patties reached an internal temperature of 74°C. Two patties for each product type and method were cooled for approximately 3 minutes, cut into 4 equal pieces, and then presented to a sensory panel consisting of 6 to 8 participants. Figure 2 shows a depiction of the sausage patty presentation that was given to each sensory panelist.
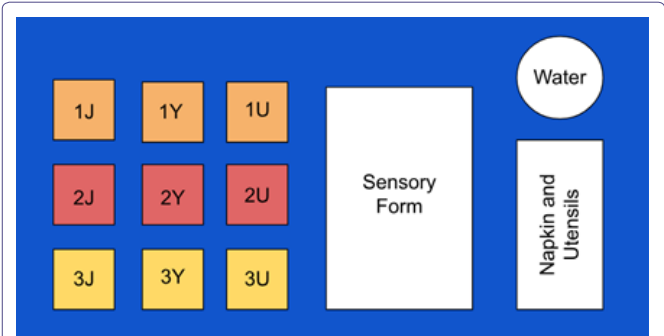

Figure 2: Layout of trays given to sensory participants.

Note: J represents Beyond Meat sausage patties; Y represents MorningStar sausage patties; U represents Jimmy Dean sausage patties; 1 represents thawing by refrigeration/refrigeration at 7°C; 2 represents thawing by microwave/refrigeration at 4°C; 3 represents thawing at room temperature/refrigeration at 1°C

For the sensory analysis, each participant was trained in three 1-hour sessions and had to assess each sample using a Freshness Quality sheet as shown below in figure 3 to rank flavor, texture, smell, appearance and overall appeal on a scale of 0-5 where 0 is unacceptable and 5 is extremely acceptable.
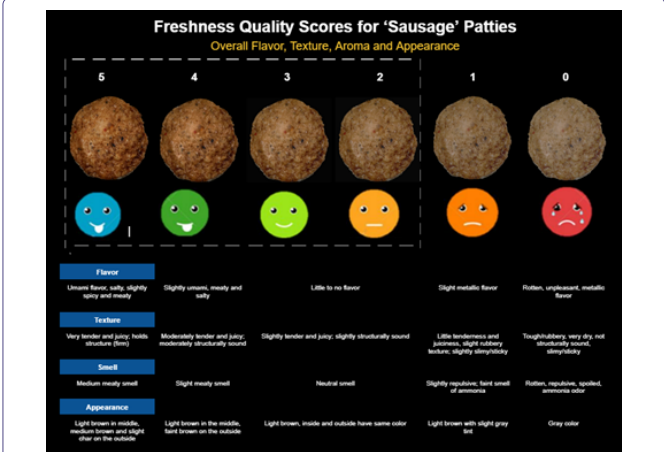

Figure 3: Freshness quality scores for sausage patties.

Color analysis was performed again using the same samples to compare differences in color after cooking. Those samples were also weighed again to determine percent cook loss and thaw loss calculated using the equation below.

$$\% \text{ Cook Loss} = \frac{\text{weight of sample after thawing(g)} - \text{weight of cooked sample(g)}}{\text{weight of sample after thawing(g)}} \times 100$$

$$\text{Total Loss} = (\text{Thaw Loss} + \text{Cook Loss})/(100 - \text{thaw loss})) \times 100$$

After weighing the samples for cook loss, the samples were analyzed for texture using the TA.XT Plus Texture Analyzer (Hamilton, MA) asset to 75% compression to obtain Texture Profile Analysis (TPA) for sample hardness, compressibility, adhesiveness and area [6]. Lastly, the pH and headspace GC were measured in duplicate on the remaining cooked samples. The pH was measured using the same procedure as previously des. Volatile and semi-volatile organic compounds were measured using a Gas Chromatograph Mass Spectrometer Agilent Technologies 7697A headspace sampler (Santa Clara, CA). The analyses were conducted by placing 0.5 to 1gram of sample in a 250µl flat bottom GC vial which was then inserted into the GC-MS. Prior to injections, samples were heated up to 260°C and held for 10 minutes. A Front SS Inlet He Agilent 122-7032UI GC column (Santa Clara, CA) was used with a thermal profile of the oven at 72°C to generate a chromatogram as seen in figure 4. Samples were analyzed further for specific volatile compounds at peak given using NIST software [7].
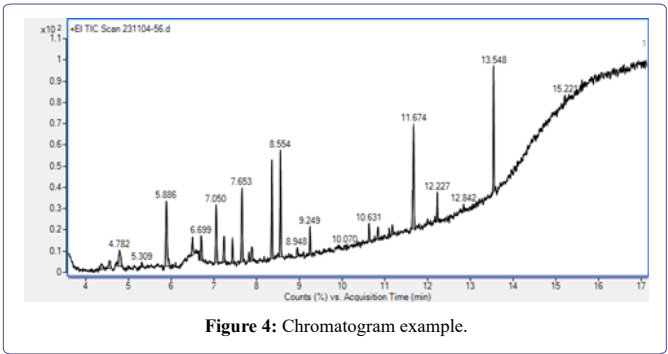

Figure 4: Chromatogram example.

This chromatogram is of Beyond Meat patty when placed in refrigerator temperature of 7°C

Statistical Analyses

Simple statistics of mean standard deviation and standard error were determined using PCSAS. Data were further analyzed using the General Linear Model (GLM) procedure in PCSAS. The overall significance of sample type and thawing method and the two-way interaction were determined using the GLM at (p≤0.05). Where overall treatments or treatment interactions were significant, means were separated using the Tukey's and least significant difference tests (p≤0.05).

Results and Discussion

Based upon visual observation, objective color values (L*a*b*), chroma and hue were expected to differ among the meat and meat analogue patties. Beyond Meat patties had the highest L* (greatest lightness) with the lowest a*, b* (redness, yellowness) and chroma values (Table 1) indicating that these patties tended to reflect more green/blue wavelengths when compared to the other patties. The lighter, less

red, and yellow color for the Beyond Meat sausage could be attributed to pea protein, a predominate ingredient, that has a more natural green color. When compared to the other patties, MorningStar® sausage had the lowest L* value (Table 1) or darkest color. This patty also had the most red/yellow tint as evidenced by the high a* and b* values, respectively (Table 1). The colorimetric properties led to a higher acceptability for MorningStar® patties and lower acceptability for Beyond Meat patties as reflected in sensory panel results shown later.

Sample[2]	Thaw Loss (%)	L*	a*	b*	Chroma	pH	TBARS (mg MDA/kg)[3]
Beyond	5.5ᵃ (±7.36)	53.2ᵃ (±3.72)	6.5ᶜ (±1.02)	19.9ᶜ (±1.71)	21.0ᶜ (±1.91)	6.77ᵃ (±0.06)	0.17ᵃ (±0.16)
Morningstar	2.3ᵇ (±2.97)	34.1ᶜ (±2.03)	12.1ᵃ (±1.75)	23.7ᵃ (±2.66)	26.6ᵃ (±2.89)	6.30ᶜ (±0.04)	0.15ᵃ·ᵇ (±0.10)
Jimmy Dean	5.5ᵃ (±7.09)	47.8ᵇ (±2.98)	8.4ᵇ (±0.65)	22.1ᵇ (±0.90)	23.7ᵇ (±1.00)	6.68ᵇ (±0.07)	0.07ᵇ (±0.01)

Table 1: Quality parameter1 results for thawed, uncooked patties for type of patty.

Note: 1. Thaw loss was calculated by taking the difference in weight between frozen sausage and thawed sausage divided by the frozen weight and multiplied by 100. L* refers to lightness, a* refers to redness, and b* refers to greenness as measured by a colorimeter. Chroma refers to the saturation of a color. TBARS (Thiobarbituric acid reactive substances) is a measure of lipid peroxidation products.

2. Beyond represents sausage patties made from Beyond Beef; Morningstar represents original flavored sausage patties made by MorningStar Farms, while Jimmy Dean refers to Jimmy Dean sausages made from pork and turkey.
a,b,c means in columns with different superscripts are significantly different (p≤0.05). Means are reported with the standard deviation in parenthesis; n=18.

3. MDA/kg = mg malondialdehyde/kg of sample.

Microwave heating accelerates rates of oxidation [8], resulting in a darker color [9], with a more brownish-red appearance. This was verified in the current study as microwave-thawed patties had significantly lower L* and hue values with higher a* values as compared to patties thawed via ambient air and refrigeration (Table 2). Morningstar patties thawed in ambient air or refrigeration displayed the highest values of a*, b* and chroma, while Beyond Meat patties thawed at room temperature had the lowest a*, b* and chroma values (Table 3). Furthermore, Morningstar samples, regardless of the thawing method used, had the lowest L* values reflecting the dark color of the sample observed during visual inspection (Table 3). Despite the browning and darkening effect microwave treatment had on the samples, the shortened thawing time of 30-35 seconds caused limited browning of samples.

Morningstar patties had significantly less thaw loss and lower pH compared to Jimmy Dean and Beyond Meat patties (Table 1). A lower thaw loss can be associated with higher quality and a lower risk of microbial contamination [10]. However, a lower pH is associated with a less tender and juicy samples [11]. The closer the pH is to the isoelectric point (pI) of proteins the lower the water-holding capacity. Lower pH can equate to darker meat because of less reflectance, but this may not be the case for meat analogues since different proteins have different isoelectric points. Proteins in Beyond patties include pea, fava bean and rice which have a pI in the 4 to 5.5 range while the protein sources used in Morningstar are wheat gluten (pI=6.4) and soy protein (pI=4.5). Soy addition dramatically decreased free water related to syneresis suggesting a competition for water between soy proteins and gluten proteins [12]. Thus the lower thaw loss for the MorningStar patties may be due to this soy-wheat protein interaction.

Thaw Method[2]	Thaw Loss (%)	L*	a*
Refrigerator	0.3[b] (±0.12)	46.6[a] (±2.03)	8.8[a,b] (±0.26)
Microwave	12.4[a] (±1.98)	42.1[b] (±1.25)	9.6[a] (±0.39)
Room Temperature	0.6[b] (±0.35)	46.5[a] (±8.64)	8.6[b] (±2.79)

Table 2: Quality parameter1 results for thawed, uncooked patties for thawing method.

Note: 1. Thaw loss was calculated by taking the difference in weight between frozen sausage and thawed sausage divided by the frozen weight and multiplied by 100. L* refers to lightness, a* refers to redness.

2. Refrigerator thawing=Patties thawed 24 hours at 4°C±2°C for 24 hours. Microwave thawing=placed in a 700 W microwave for 30-35 seconds. Room temperature thawing = Patties held at room temperature for 4 hours at 20°C±2°C

3. a,b,c means in columns with different superscripts are significantly different (p≤0.05). Means are reported with the standard deviation in parenthesis; n=18.

Sample[2]	Thaw Method[3]	Thaw Loss (%)	L*	a*	b*	Chroma
Beyond	F	0.3[c] (±0.12)	56.4[a] (±2.03)	5.9[c] (±0.26)	19.3[c,d] (±0.19)	20.1[c] (±0.20)
Beyond	Micro	15.5[a] (±1.98)	48.7[b] (±1.25)	7.9[b] (±0.39)	22.0[b] (±0.84)	23.3[b] (±0.77)
Beyond	RT	0.7[c] (±0.34)	54.7[a] (±1.27)	5.8[c] (±0.28)	18.5[d] (±1.20)	19.5[c] (±1.19)
Morningstar	F	0.2[c] (±0.27)	34.1[d] (±1.40)	12.4[a] (±2.28)	25.0[a] (±1.47)	28.0[a] (±2.21)
Morningstar	Micro	6.4[b] (±0.62)	32.8[d] (±1.39)	11.8[a] (±1.37)	20.8[b,c] (±1.43)	23.9[b] (±1.91)
Morningstar	RT	0.4[c] (±0.13)	35.4[d] (±2.47)	12.0[a] (±1.73)	25.2[a] (±2.14)	27.9[a] (±2.56)
Jimmy Dean	F	0.5[c] (±0.40)	49.3[b] (±1.38)	8.2[b] (±0.24)	22.1[b] (±0.74)	23.6[b] (±0.76)
Jimmy Dean	Micro	15.2[a] (±1.14)	44.7[c] (±1.56)	9.0[b] (±0.54)	22.2[b] (±0.71)	23.9[b] (±0.82)
Jimmy Dean	RT	0.8[c] (±0.41)	49.4[b] (±2.89)	8.1[b] (±0.71)	22.1[b] (±1.30)	23.5[b] (±1.45)

Table 3: Quality parameter1 results for thawed, uncooked patties using various thawing methods.

Note: 1. Thaw loss was calculated by taking the difference in weight between frozen sausage and thawed sausage divided by the frozen weight and multiplied by 100. L* refers to lightness, a* refers to redness, and b* refers to greenness as measured by a colorimeter. Chroma refers to the saturation of a color.

2. Beyond represents sausage patties made from Beyond Beef; Morningstar represents original flavored sausage patties made by MorningStar Farms, while Jimmy Dean D refers to Jimmy Dean sausages made from pork and turkey.

3. F represents refrigerator thawing=Patties thawed 24 hours at 4°C±2°C for 24 hours. Micro represents microwave thawing=placed in a 700 W microwave for 30-35 seconds. RT represents room temperature thawing=Patties held at room temperature for 4 hours at 20°C±2°C.

a,b,c,d means in columns with different superscripts are significantly different (p≤0.05). Means are reported with the standard deviation in parenthesis. n=6.

Beyond patties had higher pH values (Table 1) meaning the sample would be more juicy and tender [11]. Further, Beyond Beef patties had the highest TBARS values while Jimmy Dean patties had the lowest (Table 1). A higher TBARS value is associated with a higher degree of lipid oxidation [10], which leads to quality deterioration of protein [13]. Microwave treated patties had significantly higher thaw loss compared to the other patties most likely due to heating which could result in a lower quality patty (Table 2). Additionally, despite patty types, microwave thawing had the highest for thaw loss amongst the groups signifying a lower quality (Table 3).

In terms of color values, when all of the cooked samples were compared, Morningstar patties generally had the lowest L* and b* values while having the highest a* values (Table 4), which is similar to trends prior to cooking with the exception of the b* value (Table 1). Prior to cooking, the b* value for Morningstar sausage was the highest amongst the patty types (Table 1) indicating a more yellow color. The lower b* value from cooking may be a result of cooking times as Morningstar patties required an extra minute of cooking to obtain an internal temperature of 74°C compared to the other samples. The surface of Morningstar patties reduced heat penetration due to a high protein content and properties of wheat proteins [14]. Conversely, cooked sample of Jimmy Dean patties tended to have the highest b* value (Table 4) which contradicts Ryu et al. [15]. These researchers reported that plant-based meat analogs tend to have a more yellow color due to plant-based isolates and the absence of myoglobin. However, companies like Beyond Meat and Morningstar Farms try to emulate meat as closely as possible so additions of ingredients such as beet juice extract [16], and other ingredients including proteins mimicking myoglobin can be used to compensate the green and yellow colors of vegetable proteins. Furthermore, the addition of turkey in the Jimmy Dean sausage may have impacted the color since many sausage analogues try to emulate pork-only sausage.

Parameter	Sample type1		
	Beyond	**MorningStar**	**Jimmy Dean**
pH	6.69[a] (±0.09)	6.22[c] (±0.06)	6.51[b] (±0.12)
L* (lightness)	41.1[a] (±1.82)	31.5[b] (±2.81)	42.4[a] (±3.83)
a* (redness)	7.7[b] (±0.73)	12.3[a] (±1.20)	8.1[b] (±0.65)
b* (yellowness)	20.5[b] (±0.72)	20.5[b] (±0.72)	22.2[a] (±0.77)
Chroma (color intensity)	21.9[b] (±0.83)	23.2[a] (±1.84)	23.6[a] (±0.77)
Flavor2	2.8[c] (±1.07)	3.4[b] (±0.85)	3.9[a] (±1.34)
Appearance	2.8[b] (±0.82)	4.3[a] (±0.81)	2.5[b] (±1.28)
Texture	2.6[b] (±0.93)	2.9[b] (±1.05)	3.4[a] (±1.47)
Overall sensory	2.9[b] (±0.72)	3.5[a] (±0.71)	3.5[a] (±1.20)
Hardness (N)	59.5[a] (±7.48)	45.6[b] (±5.31)	44.9[b] (±10.36)
Compressibility (N)	133.0[a] (±14.70)	116.3[b] (±15.22)	141.5[a] (±19.32)
Adhesiveness (N-s)	-1.0[a] (±0.99)	-6.8[c] (±1.51)	-3.1[b] (±2.94)
Cohesiveness	-0.02[a] (±0.02)	-0.15[c] (±0.04)	-0.08[b] (±0.09)
Cook Loss (%)	28.0[a] (±6.17)	4.4[c] (±2.78)	11.0[b] (±2.60)
Total Loss (%)	35.8[a] (±5.70)	6.9[c] (±3.97)	18.0[b] (±8.19)

Table 4: Quality parameter results for cooked patties for each sample type.

Note: 1. Beyond represents sausage patties made from Beyond Beef; Morningstar represents original flavored sausage patties made by MorningStar Farms, while Jimmy Dean D refers to Jimmy Dean sausages made from pork and turkey.

a,b,c means in rows with different superscripts are significantly different (p≤0.05). n=18

2. Flavor, appearance, smell, texture, overall sensory- 5=best, 0=worst.

Jimmy Dean patties were rated highest by the trained panelists in terms of flavor and texture which may be due in part to the familiarity of the product amongst consumers (Table 4). However, it is important to remember that meat analogues are attempting to mimic meat. When volatiles were measured on the sausages, Jimmy Dean patties had the lowest amount of heptane, a compound associated with a musty off flavor even at low concentrations [17]. Whereas Beyond Meat patties had the highest amount of heptane off-flavor. This off-flavor along

with higher signs of quality deterioration, specifically higher total loss compared to other patty types, during thawing accounts for Beyond Meat patties having the lowest score for flavor and overall appeal (Table 4). Morningstar patties were the most likable for appearance which reflected the fact that Morningstar patties had the color values closely correlated with meat products, specifically a relatively high a* value, and had the lowest total loss compared to other patties (Table 4). There was no significant difference in smell or aroma observed for the different samples likely due to no noticeable spoilage of products which was reflected in no volatiles linked to spoilage from the GC volatile results.

Beyond Meat sausage had the highest values for hardness, adhesiveness and cohesiveness (Table 4). High values of hardness reflect a higher maximum force to compress [18], and therefore are the least tender samples [19], which can be attributed to higher loss of water [20]. Higher values of adhesiveness and cohesiveness relates to stickiness therefore an undesirable mouthfeel, texture, and overall eating experience [21]. Morningstar patties had the lowest compressibility/springiness, adhesiveness and cohesiveness reflecting a less "sticky" surface and better mouthfeel compared to the other sausage analogue. When the pH and cook loss of the sausage patties were compared, MorningStar had the lowest pH and cook loss while Beyond Beef had the highest pH and cook loss (Table 4) signifying that Morningstar patties retained better quality since a low cooking loss results in a more optimal eating quality and better sample appearance [22].

The only parameters that yielded significantly different values for methodology were for compressibility/springiness and cook loss (Table 5) and the only interaction that had significantly different results were for adhesiveness, cohesiveness and cook loss (Table 6). Microwave thawed samples were significantly different from other methods having the highest compressibility/springiness (Table 5) which was most likely due tough, rubbery texture from microwave electromagnetic waves [23]. Although microwave thawing had lower cooking loss values compared to other samples, the total loss was the highest, signifying a poorer eating quality. The higher total loss of microwaved patties is due to high thaw loss percent during the thawing process. Beyond patties when thawed at room temperature or under refrigeration had the highest cooking loss, adhesiveness and cohesiveness meaning it had a poorer eating quality (Table 6).

Thawing Method[1]	Compressibility (N)	Cook Loss (%)	Total Loss (%)
F	131.2[a,b] (±14.14)	15.6[a] (±1.90)	16.0[b] (±2.02)
Micro	140.0[a] (±16.47)	11.0[b] (±4.46)	27.3[a] (±4.23)
RT	119.6[b] (±14.41)	16.7[a] (±12.24)	17.4[b] (±12.43)

Table 5: Quality parameter results for cooked patties for each thawing method.

Note: 1. F represents refrigerator thawing=Patties thawed 24 hours at 4°C±2°C for 24 hours. Micro represents microwave thawing = placed in a 700 W microwave for 30-35 seconds. RT represents room temperature thawing=Patties held at room temperature for 4 hours at 20°C±2°C.

2. a,b,c means in columns with different superscripts are significantly different (p≤0.05). n=18

Sample[1]	Thawing Method[2]	Adhesiveness (N-s)	Cohesiveness	Cook Loss (%)	Total Loss (%)
Beyond	F	-1.0[a,b] (±0.98)	-0.02[a] (±0.01)	31.1[a] (±1.90)	31.5[b,c] (±2.02)
Beyond	Micro	-1.5[a,b] (±1.06)	-0.03[a,b] (±0.02)	20.5[b] (±4.46)	42.6[a] (±4.23)
Beyond	RT	-0.4[a] (±0.80)	-0.01[a] (±0.01)	32.5[a] (±1.78)	33.4[b] (±1.78)
Morningstar	F	-6.2[a,b,c] (±1.04)	-0.14[a,b,c] (±0.03)	4.9[d,e] (±1.73)	5.1[e] (±2.46)
Morningstar	Micro	-7.6[a,b] (±1.83)	-0.16[a] (±0.05)	3.6[e] (±1.91)	10.7[d] (±3.99)
Morningstar	RT	-6.6[b,c,d] (±1.63)	-0.16[b,c] (±0.04)	4.5[d,e] (±2.54)	4.9[e] (±2.44)
Jimmy Dean	F	-3.5[c,d] (±2.81)	-0.10[c] (±0.08)	10.8[c] (±2.41)	11.3[d] (±1.77)
Jimmy Dean	Micro	-1.2[d] (±1.20)	-0.02[c] (±0.03)	9.0[c,d] (±1.91)	28.6[c] (±3.26)
Jimmy Dean	RT	-4.5[c,d] (±3.83)	-0.13[c] (±0.12)	13.1[c] (±2.54)	14.0[d] (±2.68)

Table 6: Quality parameter results for cooked patties using different thawing methods.

Note: 1. Beyond represents sausage patties made from Beyond Beef; Morningstar represents original flavored sausage patties made by MorningStar Farms, while Jimmy Dean D refers to Jimmy Dean sausages made from pork and turkey.

2. F represents refrigerator thawing=Patties thawed 24 hours at 4°C±2°C for 24 hours. Micro represents microwave thawing=placed in a 700 W microwave for 30-35 seconds. RT represents room temperature thawing=Patties held at room temperature for 4 hours at 20°C±2°C.

3. a,b,c,d,e means within columns with different superscripts are significantly different (p≤0.05).Standard deviation is shown in parentheses below the mean. n=6

A total of 23 volatile compounds were identified in sausage samples from the GC-MS analysis and 10 volatile compounds having different peak area (concentration) between sausage samples are shown in table 7. MorningStar and Jimmy Dean cooked sausage had detectable concentrations of alpha-terpineol, a flavor volatile that has been found in sausage volatile profiles by several other researchers [24-26], while alpha-terpineol was not detected in Beyond cooked sausages. Shiratsuchi et al. [27], identified various volatile compounds in non-fermented sausage and also separately in spices and liquid smoke used in sausage production. Compounds found in the spice mixture that were also detected in the samples tested in the current study include ethanol (except Jimmy Dean), α-pinene, 3-carene, d-limonene, p-cymene and α-terpineol. Furfural and camphor were detected in liquid smoke by these researchers and also found in Beyond and MorningStar sausages with furfural not being detected in Jimmy Dean sausages. Thus, some of the differences in flavor volatiles between the types of sausage could be due to the proprietary spice ingredients. Furfural was detected in liquid smoke but not in the sausage mix without added smoke by Yoo et al. [28], further supporting that the differences in volatiles found in the current study may be caused by the added spice/smoke ingredients. Flores and Piornos [29], further identified α-pinene, 3-carene, and α-terpineol in spices used for fermented sausages.

Conclusion

Microwave thawed sausages had over 12 times the thaw loss and almost double the total loss compared to refrigerated and room temperature thawing and even a greater thaw loss over 15 times higher for Beyond Beef and Jimmy Dean sausages and over 6 times a greater

Volatile	Sample[1]		
	Beyond	**MorningStar**	**Jimmy Dean**
	Peak area		
Ethanol	23052[b] (±5416.25)	173006[a] (±16009.11)	ND2
α-Pinene	60655[a] (±8750.21)	16996[c] (±11963.65)	26918[b] (±5621.03)
Heptane	38575[a] (±5441.68)	25414[b] (±19942.73)	16558[c] (±4094.42)
3-Carene	38282[a,b] (±5402.03)	49891[a] (±39233.81)	30342[b] (±6676.63)
D-Limonene	42007[a] (±7440.53)	30306[b] (±22612.70)	18589[c] (±4246.03)
Eucalyptol	42016[a] (±6845.16)	47495[a] (±22692.14)	23206[b] (±6297.18)
p-Cymene	9670[a] (±1479.00)	6627[b] (±3838.17)	4038[c] (±762.06)
Furfural	60023[b] (±3732.94)	9985[a] (±5623.33)	ND
Camphor	34330[a] (±6637.42)	13197[c] (±3351.71)	19746[b] (±4284.97)
α-Terpineol	ND	18954[a] (±10767.20)	1829.6[b] (±635.10)

Table 7: GC volatile results for cooked patties for each sample type.

Note: 1.Beyond represents sausage patties made from Beyond Beef; Morningstar represents original flavored sausage patties made by MorningStar Farms, while Jimmy Dean D refers to Jimmy Dean sausages made from pork and turkey.

2. a,b,c means in rows with different superscripts are significantly different ($p \leq 0.05$). n=18. Heptane stands for Bicyclo[3.1.1] heptane, 6,6-dimethyl-2-methylene-,(1S)-. 2ND=not detected.

thaw loss for MorningStar sausages compared to the other thawing methods. This is a notable indicator of a lower quality sausage and sausage analogue as higher thaw loss is a results of cellular and tissue damage causing a loss of flavor. Other significant differences between microwaved samples and samples that were thawed under refrigeration or at room temperature were water activity, L*, a*, compressibility/springiness and cook loss. Microwave samples had significantly lower water activity and cook loss which is generally associated with a higher quality product. However, the magnitude of difference in thaw loss for microwave thawing overshadowed the lesser differences in cook loss compared to the other thawing methods. Significantly lower L* value and significantly higher a* and springiness values for microwaved samples were a result from high thaw loss yet made no significant difference in the sensory panel results.

Despite the significant impact of microwaved samples for thawing, samples were the largest indicator of quality with Morningstar patties having the most favorable results as best reflected by moisture content and sensory trials. Morningstar patties had nearly twice as high scores for appearance compared to Beyond and Jimmy Dean patties and had a significantly higher cook yield and significantly lower cooking loss, drip loss and total loss.

Conflict of Interest

There is no conflict of interest for this study. Technical Contribution No. 7270 of the Clemson University Experiment Station.

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