Quality of Restructured Beef Steaks After Refrigerated and Frozen Storage 1

H. W. OCKERMAN* and C. S. ORGANISCIAK 2

Animal Science Department,
The Ohio State University, Columbus, Ohio 43210 and
The Ohio Agricultural Research and Development Center,
Wooster, Ohio 44691

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ABSTRACT

This experiment evaluated a procedure for converting forequarter beef tissue into a fabricated steak-like product and to test its refrigerated and frozen storage characteristics. The restructured steaks were manufactured by tumbling thin slices of beef arm chuck roast with salt (2%) and added water (3%) and then passing this product through a mechanical patty machine. Refrigerated and frozen storage characteristics. The restructured steaks were evaluated at 0, 1, 2, and 3 months of storage. An acceptable steak-like product was manufactured; however its raw visual appearance and raw odor deteriorated quickly and its cooked palatability characteristics deteriorated with both types of storage, probably due to oxidation.

The concept of restructuring meat is not new and has its origin in loaf and casing-type products that were cooked to bind the tissues. Meat patties are also an attempt to form larger pieces of meat from ground product in the uncooked state. These types of products, however, have a texture that is characteristic of comminuted meat. Recently, many technological advances and processing combinations have been used in attempts to make the restructured product more closely resemble a solid piece of meat from the textural standpoint (3, 6, 11, 13, 14, 20, 22).

Mandigo (1) identified some of the advantages of restructuring meat which included better utilization of lower value meat resources and increased processor control over physical and chemical composition of the product. The flake cutting method for preparing meat for restructuring increases cohesiveness and bind when compared to a ground product. Flaked-cut patties can be used in the place of ground patties when a coarser grind and a more steak-like texture are desired. Flaked-cut patties display greater cohesiveness and bind and have a less greasy organoleptic quality than ground patties (21).

Flaked products have also been shown to possess greater water holding capacity (12) than ground patties.

Tumbling or massaging is a rather recent technique (10, 17, 18, 19, 23, 25, 27, 29) for mechanically agitating muscle tissue and extracting a protein exudate which will improve binding characteristics. This method can be used to bond together pieces of meat. Adding salt in the amount of at least 0.6% helps extract salt-soluble proteins to the meat surface (31). As salt level and massaging times increase, the amount of protein in the exudate increases (26, 30). Salt at 2% appears to be optimal (27).

The objective of this research was to utilize the tumbling technique as part of a process for fabrication of restructured meat and to evaluate this product during both refrigerated and frozen storage.

MATERIALS AND METHODS

Preliminary research evaluated such factors as beef tissue types (round, chuck, shank tissue from Standard through Choice grades), chilling temperatures (-3, 0, 3, 6, and 9 C), grinding (4, 7, 9, 5, and 22.2-mm plates) and slicing (1, 3, 6 and 9 mm) to alter meat particle sizes, salt (0, 1, 2 and 3%) and moisture levels (0, 1, 3, and 5% addition), tumbling duration (10 min/h for 1, 3, 6, 9 and 12 h), and patty-forming techniques (hand and machine patties of 75, 100, and 140-g sizes). The most successful (fresh appearance and organoleptic characteristic) combinations were used in this research project.

This experiment used muscle tissue from U.S. Good grade beef arm chuck roasts which weighed approximately 4.5 kg. This tissue was cooled to 0 ± 1 C and sliced on a Hobart Slicer to a thickness of 3 ± 0.5 mm. As nearly as possible, slicing was accomplished perpendicular to the muscle fiber, yielding approximately 75% perpendicular slices and the remaining 25% varying from this position to parallel to the muscle fiber.

To the raw meat, 2% salt and 3% water (based on meat block) were added and all ingredients were mixed together and placed in a tumbler constructed at Ohio State University. This equipment was manufactured from a stainless steel drum (86-cm diameter and 85-cm depth) containing three baffles. The tissue was tumbled in a 2 ± 2°C cooler, for 10 min out of each hour, for 6 h at 12 revolutions per min.

The tumbled beef tissue was formed into 24 oval-shaped patties (140 ± 5 g weight, 14.7-cm length, 10.2-cm width, and 1.2-cm thick) by

1Approved for Publication as Journal Article 8-78 of The Ohio Agricultural Research and Development Center, Wooster, Ohio 44691.
2Ministry of Agriculture, Vet. Dept., 30 Wspolna, Warsaw, Poland.
a Hollymatic Patty Machine, Model #500. Salt and proximate analyses were done by modified (16) AOAC methods on each production lot.

Patties were packaged three per Barrier Bag (Cry-O-Vac Type B-620 Barrier Bag – water vapor transmission, 0.5 - 0.6 g per 645 cm² in 24 h at 38 C and 100% relative humidity; oxygen transmission, 30-55 cc per m² in 24 h at 23 C and one atmosphere) and the air was evacuated by a Cry-O-Vac laboratory vacuum pump (Model Number CV-U) to 450 ± 25 mm of mercury. The bags were closed using a Poly-Clip Applicator Unit (Type SCH210) and were visually checked after storage.

From each of the six production lots, a sample of three patties (140 ± 5-g each) for each sampling period were packaged together and stored for 0, 3, 6 and 10 days at 4 ± 2 C and an equal number of samples (patties) from the same production lot were frozen at -23 ± 3 C, stored for 0, 1, 2 and 3 months in a freezer at -23 ± 3 C and thawed (5 h at 20 ± 3 C) before evaluation and cooking.

After being stored under these conditions, patties were evaluated by a six-member trained panel to determine the individual levels of each character of quality such as color, odor, and cohesiveness of the raw product. All panel members had at least 5 years of meat panel experience and were given samples, during training, of the extremes of all factors to be evaluated. The evaluation scale ranged from 1 (faint, dry, heavy meat odor, not cohesive) to 10 (dark, fresh, flesh meat odor, very cohesive). After each storage treatment, the raw beef tissue was examined for aerobic and anaerobic organisms.

Aerobic organisms were determined by standard techniques (16) using Tryptone Glucose Extract Agar and incubating at 25 C for 48 h. Anaerobic organisms were also determined by standard techniques using Baltimore Biological Laboratory (BBL) Anaerobic Agar and incubating in a CO₂ atmosphere at 25 C for 5 days. In both instances the number of organisms were expressed as the log of the number per gram of tissue.

Rancidity of the raw tissue was determined by TBA analysis (16) and pH was measured with a Beckman Expandomatic SS-2 pH meter (16).

Patties were broiled (approximately 5 min first side, 3 min second side) in a Hotpoint Broiler (Model #201B7), to an internal temperature of 65 ± 2 C and each characteristic of quality was evaluated for visual acceptability, cohesiveness, odor, texture, tenderness, flavor, juiciness, and general acceptability by the same trained panel (different time) using the same (1 state appearance, not cohesive, fresh meat odor, crumbly texture, extremely tough, stale flavor, dry, unacceptable) to 10 (fresh appearance, very cohesive, fresh meat odor, solid meat texture, extremely tender, fresh flavor, very juicy, acceptable) scale.

This experiment was replicated six times and the data were analyzed by Harvey’s (9) Least Squares Analysis of Data with Unequal Subclass Frequency.

RESULTS AND DISCUSSION

Non-stored product characteristics

Analysis of the raw patties indicated their composition was as follows: protein 16.9 ± 0.9%, fat 14.7 ± 4.1%, moisture 65.9 ± 3.8%, ash 2.9 ± 0.4% and salt 2.1 ± 0.4%. The results of this research indicate that an acceptable product was produced by the tumbling method of manufacturing restructured steaks (Table 1). All quality attributes of the raw product immediately after manufacture were in the range normally expected for steak-like products when compared with previous steak taste panels from this same laboratory and with the same panel members. The uncooked color darkened (P < 0.05) during freezing-thawing and the uncooked odor scores also decreased (more stale) at the P < 0.05 level. All other uncooked product attributes remained relatively constant during freezing-thawing. Cooking the non-stored product resulted in a very acceptable steak-like product. Cohesiveness and odor were improved by cooking (Table 1).

Other characteristics of the cooked product (visual acceptability, steak texture, tenderness, flavor, juiciness and general acceptability) were in a range considered acceptable for cooked steak products (previous steak panels, same laboratory). Freezing and thawing (Table 1) had no real effect on any of the cooked quality attributes.

| Parameters evaluated | Ref. storage 0-days Least square mean Change during freezing and thawing |
|----------------------|---------------------------------|-----------------------------|
| Uncooked color       | 6.63                            | + 1.08 *                    |
| Uncooked odor        | 7.23                            | - 1.16 *                    |
| Uncooked cohesiveness | 7.50                           | - 0.9 NS                    |
| Cooked visual acceptance | 8.05                        | + 0.12 NS                   |
| Cooked cohesiveness  | 8.05                            | + 0.22 NS                   |
| Cooked odor          | 8.02                            | - 0.05 NS                   |
| Cooked steak texture | 7.22                            | + 0.02 NS                   |
| Cooked tenderness    | 8.10                            | - 0.20 NS                   |
| Cooked flavor        | 8.20                            | - 0.35 AS                   |
| Cooked juiciness     | 7.75                            | - 0.30 NS                   |
| Cooked general acceptability | 8.10                        | - 0.17 NS                   |
| Uncooked aerobic (log/g) | 5.31                        | + 0.03 NS                   |
| Uncooked anaerobic (log/g) | 3.47                        | + 0.55 NS                   |
| Uncooked TBA number  | 2.28                            | + 2.72 AS                   |
| Uncooked pH          | 5.60                            | - 0.00 NS                   |

*NS = non-significant; AS = approach significance, 10% level.
* = significance at 5% level.
$ = light, 10 = dark.
$ = state meat odor, 10 = fresh meat odor.
$ = very cohesive, 10 = not cohesive.
$ = state appearance, 10 = fresh appearance.
$ = not cohesive, 10 = very cohesive.
$ = state meat odor, 10 = fresh meat odor.
$ = crumbly texture, 10 = solid meat texture.
$ = extremely tough, 10 = extremely tender.
$ = state flavor, 10 = fresh flavor.
$ = dry, 10 = very juicy.
$ = unacceptable, 10 = acceptable.

Stored product characteristics

Uncooked product evaluation. Uncooked product color scores increased (darker) significantly (Table 2) during refrigerated (P < 0.05) and frozen storage (P < 0.01). The largest increases occurred during freezing-thawing and in early stages of refrigerated storage. This darkening in raw product color agrees with results of Schwartz et al. (24) for flake-cut restructured pork. Gokalp (7) found little color change in a vacuum-packed ground beef patty (no NaCl) that had been stored at -22 C for 135 days. Uncooked product color scores from the refrigerated product showed a positive correlation (Table 3) with raw TBA values (P < 0.01). The same was true for frozen patties (P < 0.05). The increase in TBA values (Table 2) suggests fat oxidation during storage. The literature (8,15) suggests this was probably accelerated by the salt and retarded by vacuum packaging.

Uncooked product odor became more stale (P < 0.05) during refrigerated storage (Table 2). The same decrease was noted with the frozen product up to 60 days, after
which the values stabilized and remained relatively constant. These lower panel uncooked product odor
scores during refrigerated storage (Table 2) are in accordance with increased TBA values. The correlation
(Table 3) with TBA was negative (r = -0.79, P < 0.01) during refrigerated storage and was also negative
(r = -0.25) during frozen storage but not at a significant level. Uncooked TBA values (Table 2) increased
(P < 0.05) during refrigerated storage of the restructured samples. The uncooked TBA values in the frozen
samples fluctuated over time. This suggests that the decrease in odor desirability is at least partially due to
the presence of products from oxidative processes that occurred during storage.
Aerobic bacteria counts increased (P < 0.01) with refrigerated product storage time, but remained relatively
unchanged in frozen samples (Table 2). The difference is most likely due to storage temperature
differences. Anaerobic counts increased in the refrigerated product up to the sixth day, then decreased.
Anaerobic counts remained relatively stable in the frozen product.
Cohesiveness was very acceptable as rated by the panel. The product approached a solid piece of meat in
appearance and texture. Cohesiveness values remained relatively constant during both refrigerated and frozen
storage (Table 2).
Cooked evaluation. Cooking the tissue gave higher (Table 2) visual acceptability scores than those of
uncooked tissue of the refrigerated product. Cooking slightly lowered visual acceptability scores in the
freezer-stored product. An explanation for this difference was the darkening (P < 0.05) of color during freezing (Table 1). Cooking greatly improved low uncooked product odor scores; however, it did not change the general downward trend that occurred over storage time (Table 2).
Cohesiveness scores were slightly higher (Table 2) for the cooked than the uncooked product. As with raw
samples, length or type of storage had little or no effect on cohesiveness values.
In both the refrigerated and frozen phase, cooked steak texture decreased slightly (Table 2) during storage
but remained very acceptable for all samples evaluated. There appeared to be no real difference between cooked
steak texture scores for these two types of storage procedures. As would be expected, steak texture scores
were positively and significantly correlated (P <0.01) with cooked product cohesiveness scores (Table 3).
Cooked product tenderness scores (Table 2) from the refrigerated product remained relatively constant during
storage; while the scores for frozen products decreased slightly but again remained in an acceptable range
(previous steak panel, same laboratory).
Mean scores for steak texture (Table 2), indicate that this new method of forming steak-like product resulted
in a product with a desirable steak texture. Furthermore, this desired texture was accompanied by an acceptable
degree of tenderness.
Length storage time for refrigerated and frozen products (Table 2) decreased cooked product flavor
scores. This trend was more pronounced in the non-frozen samples. Flavor scores of the refrigerated
product correlated (P <0.01) with TBA values (r =

### TABLE 2. Least squares mean for variables during storage.

<table>
<thead>
<tr>
<th>Days</th>
<th>Refrigerated storage, days</th>
<th>Frozen storage, days</th>
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</thead>
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<tr>
<td></td>
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<tr>
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<tr>
<td>Cooked cohesiveness</td>
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<td>8.14</td>
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<td>8.05Q+</td>
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<td>Cooked steak texture</td>
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<td>8.10</td>
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<td>Cooked flavor</td>
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<td>Cooked juiciness</td>
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<td>Uncooked aerobic (log/g)</td>
<td>5.31L**</td>
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</table>

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**Significance:** L = linear, Q = quadratic, C = cubic, * = 5% level of significance, ** = 1% level of significance.

b1 = light, 10 = dark.
c1 = stale meat odor, 10 = fresh meat odor.
d1 = very cohesive, 10 = not cohesive.
e1 = stale appearance, 10 = fresh appearance.
f1 = not cohesive, 10 = very cohesive.
g1 = stale meat odor, 10 = fresh meat odor.
h1 = crumbly texture, 10 = solid meat texture.
i1 = extremely tough, 10 = extremely tender.
j1 = stale flavor, 10 = fresh flavor.
k1 = dry, 10 = very juicy.
l1 = unacceptable, 10 = acceptable.
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<th>Characteristic</th>
<th>Uncooked pH</th>
<th>Uncooked TBA</th>
<th>Uncooked anaerobic</th>
<th>Uncooked aerobic</th>
<th>Cooked general accept.</th>
<th>Cooked juiciness</th>
<th>Cooked flavor</th>
<th>Cooked tenderness</th>
<th>Cooked steak texture</th>
<th>Cooked odor</th>
<th>Cooked cohesiveness</th>
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<th>Cooked cohesiveness</th>
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<th>Uncooked anaerobic</th>
<th>Uncooked pH</th>
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<td>-0.03</td>
<td>0.71**</td>
<td>0.45*</td>
<td>0.59**</td>
<td>-0.48**</td>
<td>-0.09</td>
<td>-0.70**</td>
<td>-0.35</td>
<td>-0.32</td>
<td>-0.44**</td>
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<td>-0.43**</td>
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<td>0.34</td>
<td>0.60**</td>
<td>0.44**</td>
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<td>0.01</td>
<td>0.35</td>
<td>0.44*</td>
<td>0.21</td>
<td>0.48**</td>
<td>-0.07</td>
<td>0.09</td>
<td>0.51**</td>
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<td>0.06</td>
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<td>0.52**</td>
<td>0.24</td>
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<td>0.03</td>
<td>0.27</td>
<td>0.16</td>
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<td>0.28</td>
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<td>0.67**</td>
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<td>0.73**</td>
<td>0.43**</td>
<td>0.34</td>
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<td>-0.48*</td>
<td>0.50*</td>
<td>0.50*</td>
<td>0.79**</td>
<td>0.57**</td>
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<td>-0.36</td>
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*Upper-left = refrigerated; lower-right = frozen.
** - 5% level of significance
*** - 1% level of significance
Cooked product juiciness scores remained relatively constant and at a desirable level (compared with previous steak results, same laboratory) during both refrigerated and frozen storage (Table 2). General acceptability scores decreased ($P < 0.01$) during both types of storage (Table 2).

This restructured product is very acceptable in the fresh state. However, rapid deterioration occurs in uncooked product color and odor and the stored product is also rated lower with longer storage time when cooked product odor, flavor, and general acceptability are compared. Fat oxidation, based on TBA values, is an important factor in this deterioration. If the product cannot be used quickly it appears that phosphates or antioxidants will be necessary for an acceptable shelf life.

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