1995

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Wesley Osburn
University of Nebraska - Lincoln

Roger W. Mandigo
Universit y of Nebraska - Lincoln, rmandigo1@unl.edu

Paul Kuber
University of Nebraska - Lincoln

Osburn, Wesley; Mandigo, Roger W.; and Kuber, Paul, "Utilization of Twin Screw Cold Extrusion to Manufacture Restructured Chops from Lower-Valued Pork" (1995). *Nebraska Swine Reports*. 174.
http://digitalcommons.unl.edu/coopext_swine/174

Utilization of Twin Screw Cold Extrusion to Manufacture Restructured Chops from Lower-Valued Pork

Wesley N. Osburn
Roger W. Mandigo
Paul S. Kuber[1]

Restructured meat products are commonly manufactured by using lower-valued meat trimmings reduced in size by comminution (flaking, chunking, grinding, chopping or slicing). The comminuted meat mixture is mixed with salt and water to extract salt-soluble proteins. These extracted proteins are critical to produce a "glue" which binds muscle pieces together. These muscle pieces may then be reformed to produce a "meat log" of specific form or shape. The log is then cut into steaks or chops which, when cooked, are similar in appearance and texture to their intact muscle counterparts.

Two concerns must be addressed in the manufacture of restructured meat products: texture, and the removal and degradation of connective tissue. Lower-valued meat trimmings used in restructuring tend to contain more connective tissue which may affect product texture.

Mechanical desinewing is used to remove connective tissue from boneless meat trimmings. Reducing the connective tissue in trimmings increases their value for use in various restructured meat products. The method of comminution also affects the final product texture, which usually is somewhere between that of ground (hamburger) and an intact muscle (steak or chop) meat product.

Recently, twin screw cold extrusion has been used as a processing technology to produce restructured meat products. In this process, a comminuted meat mixture is forced to flow through an enclosed twin-screw extruding horn to form "extruded ropes" of a specific shape and size. These ropes can be pressed together to form meat logs which then can be cleaved into restructured steaks or chops. This process is believed to partially realign muscle fibers and modify the texture of meat products.

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This study sought to evaluate various mixing times and extrusion speeds on the sensory and textural attributes of cold extruded restructured pork chops.

Materials and Methods

Manufacturing. Fresh, boneless pork blade loin meat and desinewed pork shank meat were obtained from a commercial source. Blade meat was coarse ground using a 1" plate and the pork shank meat was desinewed to produce comminuted meat trimmings with a diameter of 3/16 in. Batches (70% blade and 30% shank meat) were preweighed (13.6 kg) and held in a cooler at 36°F for 24 hours before mixing.

Salt (0.25%) and sodium tripolyphosphate (0.5%) were added to all extruded pork chop treatments. The meat blocks were mixed in a paddle-mixer for 20 or 40 minutes. Salt and sodium tripolyphosphate were added during the initial mixing period (within 1 min of start time). The mixed meat blocks were bagged in polyethylene, labeled, placed in tubs and stored in a cooler (36°F) until they were extruded.

Extrusion. A Wenger TX 52 twin screw extruder with a screw configuration, consisting of 3/4" pitch screws, 1/2" pitch screws, cone screws, circular locks and shearlocks was used. The twin screws moved in a co-rotating motion as the meat mixture was conveyed through a 1/2" diameter circular extruder horn equipped with a cold water jacket maintained at 36°F. Extrusion speeds of 200, 300 and 400 rpm were used to produce extruded "ropes" which were placed on stainless steel trays lined with polyethylene. Product was frozen for 6 hours at -10°F then tempered for 12 hours at 26°F.

Approximately 12-15 tempered, extruded ropes were pressed into large diameter logs resembling a boneless pork loin roast. The logs were cleaved into 1" thick chops, vacuum sealed in commercial film and stored at -20°F for two weeks before analysis. Boneless pork loin chops from the center loin were chosen for the control. Chops (1" thick) were removed from the center loin, trimmed of all visible subcutaneous fat, packaged and stored in the same manner as the extruded pork chops. Fresh extruded and control chops were evaluated for proximate composition (moisture, fat, protein and ash) and color (lightness, redness and yellowness).

Cooking Procedures and Analyses. Extruded and control pork chops were tempered at 32°F for 12 hours and cooked on a flat-top grill pre-heated to 350°F. Extruded and control chops were cooked to an internal temperature of 160°F and blotted with paper towels after cooking to remove excess grease. Four control chops and four extruded chops from each treatment were evaluated for cooking yield, cooked color and proximate composition. Cooked control and extruded chops were compressed to 25% of original chop height with an Instron Universal Testing Machine. A two-cycle compression was used and values from the compression curves were used to calculate hardness (peak force of compression cycle 1), cohesiveness (area under curve 2 / area under curve 1), springiness (width of compression cycle 2) and chewiness (hardness x cohesiveness x springiness). Tenderness of extruded and control pork chops were determined using a L.E.E.-Kramer shear apparatus attached to the Instron.

Cooked control and extruded pork chops were cut into 1/2-inch cubes and served warm to a consumer sensory panel. Samples were evaluated for texture, flavor, juiciness and overall acceptability on an eight-point hedonic scale where 1=extremely undesirable and 8=extremely desirable.

Scanning Electron Microscopy. Scanning electron microscopy was used to determine the degree of muscle fiber alignment of cooked extruded and control chops. Cryofractured samples (1/16 in cubes) were fixed in a 1.25% glutaraldehyde solution (12-16 hr), washed (2X) in a buffered (pH 7.4) solution and post-fixed (1 hr) in 1% osmium tetroxide. Samples were serially dehydrated in graded ethanol, critical point dried, mounted and sputter-coated with 300 angstroms of gold/palladium. An accelerating voltage of 10 kilovolts and a 100 micron aperture were used to obtain scanning electron micrographs at magnifications from 100-400X.

Statistical Analysis. Data were analyzed as a 2 x 3 factorial arrangement of treatments in a randomized complete block design. Mixing time (20 or 40 minutes) and extrusion speed (200, 300 or 400 rpm) were the main effects. Significant effects were defined to be those with $P<.05$. Means were separated using Fisher's Least Significant Difference (LSD) test.

Results

Differences due to extrusion speed, mixing time or the combined effect of extrusion speed and mixing time were not significant for any of the variables tested. Raw and cooked control chops had more moisture and protein than extruded chops (Table 1). Extruded chops (raw and cooked) had more fat and ash than control chops.

Extruded chops were formulated with 70% blade meat which contained 29% fat, explaining the difference in fat content between the extruded and the control chops. Differences in ash content were probably due to addition of salt and phosphate in extruded chops. Cooking yields (Table 1) were greatest for the 20 min/200 rpm and 40 min/400 rpm extruded chops (74.17 and 75.75%, respectively) and least for 40 min/200 rpm extruded chops and control chops (71.84 and 72.43%, respectively).

Raw and cooked control chops were lighter in color than extruded chops (Table 2). Raw extruded chops were redder and more yellow than control chops. These color differences may be due to the darker lean color contributed by the blade and shank meat used to formulate extruded chops compared to the lighter colored longissimus muscle of control chops. After cooking, this relationship changed.

Cooked control chops were redder and more yellow than extruded chops. Dispersion and amount of fat particles in extruded chops may be responsible for the color differences observed.

Sensory scores for each extruded

Table 1. Effect of mixing time (min) and extrusion speed (rpm) on proximate composition and cooking yields of cold, extruded, restructured pork chops.

	Treatments[a]							
Variable	20 min/ Control	40 min/ 200 rpm	20 min/ 200 rpm	40 min/ 300 rpm	20 min/ 300 rpm	40 min/ 400 rpm	400 rpm	S.E.[b]
Raw								
Moisture, %	67.82*	62.57	61.77	62.00	61.34	62.36	62.24	1.34
Fat, %	10.35**	20.12	21.60	21.11	22.08	20.92	19.45	1.69
Protein, %	22.53**	17.35	16.78	16.82	16.70	16.79	17.34	0.59
Ash, %	1.01**	1.32	1.27	1.31	1.52	1.38	1.37	0.04
Cooked								
Moisture, %	56.8*	53.8	52.3	52.0	53.2	52.6	51.9	1.30
Fat, %	12.5**	25.1	24.5	23.7	23.9	24.4	24.4	2.07
Protein, %	31.1*	22.6	22.3	23.5	22.0	22.1	22.6	0.63
Ash, %	1.20**	1.77	1.80	1.78	1.78	1.81	1.69	0.70
Cooking Yield								
Yield (%)	72.43[cde]	74.71[ef]	71.84[cd]	70.59[c]	75.20[ef]	74.32[def]	75.75[f]	0.80

[a] Control = boneless loin chops; Treatments: mixing time = 20 or 40 min; extrusion speed = 200, 300 or 400 rpm.

[b] S.E. = Standard Error

[cdef] Treatments with different superscripts differ (P<.05)

*The control is significantly different from extruded chops (P<.05).

** The control is significantly different from extruded chops (P<.01).

Table 2. Effect of mixing time (min) and extrusion speed (rpm) on raw and cooked color of cold, extruded, restructured pork chops.

	Treatment[a]							
Variable	20 min/ Control	40 min/ 200 rpm	20 min/ 200 rpm	40 min/ 300 rpm	20 min/ 300 rpm	40 min/ 400 rpm	400 rpm	S.E.[b]
Raw Color								
"L"[c]	41.0*	47.9	50.0	47.2	48.9	47.2	50.1	1.15
"a"[d]	12.8*	19.9	21.6	23.2	21.6	21.7	22.3	12.8
"b"[e]	3.4*	6.5	6.9	6.6	6.7	6.4	6.7	0.07
Cooked Color								
"L"	39.8*	32.2	32.5	29.8	32.7	33.6	32.6	1.06
"a"	16.8*	12.4	13.3	13.3	13.9	12.2	14.0	0.35
"b"	9.32*	6.64	7.33	6.63	7.32	7.07	7.25	0.26

[a] Control = boneless loin chops; Treatments: mixing time = 20 or 40 min; extrusion speed = 200, 300 or 400 rpm.

[b] S.E. = Standard Error.

[c] Lightness Scale: 100 = White, 0 = Black.

[d] Redness: Larger number indicates more red.

[e] Yellowness : Larger number indicates more yellow.

* Control was different from extruded chops (P<.01).

Table 3. Effect of mixing time (min) and extrusion speed (rpm) on sensory and textural attributes of cold, extruded, restructured pork chops.

	Treatment[a]							
Variable	20 min/ Control	40 min/ 200 rpm	20 min/ 200 rpm	40 min/ 300 rpm	20 min/ 300 rpm	40 min/ 400 rpm	400 rpm	S.E.[b]
Sensory Attributes[c]								
Juiciness	4.5*	6.7	6.5	6.5	6.4	6.5	6.3	0.13
Texture	5.1*	5.8	5.8	6.0	5.7	5.8	6.0	0.17
Flavor	5.4*	6.4	6.3	6.3	6.0	6.1	6.1	0.16
Overall Acceptability	4.9*	6.2	6.0	6.1	5.9	6.0	6.0	0.17
Textural Attributes								
Hardness[d]	415.13*	139.50	117.25	118.75	133.88	126.13	133.5	9.72
Cohesiveness[e]	0.43*	0.28	0.29	0.29	0.28	0.28	0.28	0.03
Springiness[f]	15.13*	19.00	19.63	19.00	18.63	19.50	18.88	0.58
Chewiness[g]	2693.16*	744.63	675.33	649.43	695.83	694.16	698.79	92.87
Shear Force (kg/g)[h]	8.54*	4.23	4.63	5.45	4.60	4.77	4.91	0.34

[a] Control = boneless loin chops; Treatments: mixing time = 20 or 40 min; extrusion speed = 200, 300 or 400 rpm.

[b] Standard Error

[c] Sensory Scale: 1 = Extremely undesirable, 8 = Extremely desirable.

[d] Peak Force (kg / gram of compression cycle 1 (CC1).

[e] Area Under the Curve (AUC) of Compression Cycle 2 (CC2)/ AUC of CC1

[f] Width of CC2 (mm).

[g] Hardness * Cohesiveness * Springiness (kg * mm / gram of sample)

[h] Kilogram force per gram of sample

* The control is significantly different from extruded chops (P<.01).

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Figure 1. **Micrograph of cooked extruded pork chop sample (20 min/200 rpm). Muscle fibers (a) appear to be aligned. Arrow points to fat globule. Bar scale = 25 microns.**

Figure 2. **Micrograph of cooked extruded pork chop sample (40 min/ 400 rpm). Arrow points to muscle fibers. Bar scale = 100 microns.**

Figure 3. **Micrograph of cooked extruded pork chop sample (40 min/ 200 rpm). Linearly arrayed muscle samples (a), possible single muscle fiber (b), and an area of emulsion-like, less ordered fibers (c) are identified. Bar scale = 100 microns.**

Figure 4. **Linearly arrayed muscle fibers of a cooked, intact muscle boneless pork chop control. Bar scale = 100 microns.**

pork chop treatment and control chops are reported in Table 3. Scores for extruded pork chops were greater than control chops for sensory juiciness, texture, flavor and overall acceptability. Greater fat content (24%) in extruded chops compared to control chops (12.5%) may be responsible for this difference. Extrusion has been hypothesized to increase textural properties in restructured products by possibly re-aligning the muscle fibers of comminuted meat particles to form a more structured arrangement of muscle fibers, similar to that of intact whole muscle. This might explain the higher textural scores for extruded chops.

Control chops were harder and chewier than the extruded chops (Table 3). Extruded chops were springier, less cohesive and required less peak force to shear than control chops. This again may be caused by the higher fat content in extruded chops, resulting in less extracted myofibrillar protein available for protein-protein interactions associated with meat binding, a direct influence on product texture and success of a restructured product.

Scanning electron microscopy was used to determine the degree of muscle fiber alignment of cooked extruded and control chops. Figure 1 is a micrograph from an extruded pork chop sample mixed for 20 min and extruded at 200 rpm. The sample appears to contain areas of partially realigned, somewhat linearly arrayed muscle fibers. Figure 2 shows a 40 min, 400 rpm extruded pork chop sample also containing slightly realigned muscle fibers with areas that appear to contain emulsion-like, less-ordered material. This emulsion-like material is probably the desinewed pork shank meat which filled in the gaps between muscle fibers during the restructuring and extrusion process. The apparent non-realignment of the muscle fibers of desinewed shank meat may be explained by its smaller particle size (1/4" in diameter) compared to the diameter (1/2") of the extruding horn. Particle sizes smaller than the diameter of the extruding horn may not be forced to flow in a “one way” direction resulting in little realignment of muscle fibers.

Figure 3 is a micrograph from a 40 min, 200 rpm extruded pork chop sample which indicates distinct areas of linearly arrayed muscle fibers composed of chunked pork loin blade meat and emulsion-like, less-ordered areas containing desinewed pork shank meat. Figure 4 shows the well-ordered muscle fiber structure of an intact boneless pork chop control.

Conclusion

Twin screw cold extrusion technology can be used to manufacture restructured meat products. Extruded pork chops manufactured from lower-valued pork loin blade meat and desinewed pork shank meat had desirable sensory and textural attributes which were equal to or better than the intact boneless pork chop control. Scanning electron microscopy of cooked extruded and control pork chop samples suggest that part of the reason for the desired textural attributes observed in extruded chops may be due to partial realignment of muscle fibers.

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[1] Wesley N. Osburn is a graduate student, Roger W. Mandigo is a professor with the Department of Animal Science, and Paul S. Kuber is with Superior Packing Co., Dixon, CA.