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

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vitamin B-6, vitamin E, iron, magnesium, zinc, and selenium. The amounts of these nutrients in the cooked pork roasts and their retention values were determined. Thiamin was used as the index nutrient. Cooked pork roasts (3.5 ounces) were found to contain approximately 20% of the vitamin B-6, 49% of the thiamin, 2% of the vitamin E, 10% of the iron, 6% of the magnesium, 20% of the zinc, and 89% of the selenium needed to meet the Recommended Dietary Allowances of adults for a day.

True retention is a term that relates the percentage of nutrient content of the food as cooked to the content before cooking. The true retention of the vitamins in the pork roasts prepared by the three cooking methods to the two internal temperatures are given in Figure 1. Retention values for vitamin B-6 and thiamin were significantly higher (P < .01) in pork cooked to 160° F than to 180° F. Vitamin B-6 retention values for pork cooked in a bag were significantly higher (P < .01) than for pork that was

roasted, whereas pork that was roasted had significantly higher (P < .01) values than pork that was braised. Thiamin retention values were significantly higher (P < .01) in pork that was cooked in a bag or roasted than in pork that was braised. Mean true retention values were 58% for vitamin B-6 and 51% for thiamin. Hence, almost half of the vitamin B-6 and thiamin were destroyed during cooking. The highest true retention values for these two vitamins were for pork cooked in a bag.

The vitamin E retention in pork prepared by the different cooking: temperature methods was similar. The pork roasts contained a small amount of vitamin E, only enough to meet about 2% of recommended intakes per serving. However, the mean true retention value for vitamin E was only 44%, indicating that over half of the vitamin E was destroyed during cooking. This was independent of the cooking: temperature method used. The lower fat trim of today's pork cuts may result in the lower vitamin E content.

True retention values for iron, magnesium, zinc, and selenium were similar for the different cooking: temperature methods and were close to 100%. Hence, no loss of minerals occurred while the pork was being cooked.

True retention values for vitamin B-6, thiamin, and vitamin E were highest for pork roasts cooked in the bag to an internal temperature of 160° F. However, true retention values for iron, magnesium, zinc, and selenium were similar in pork cooked in the bag, braised, or roasted to either 160° or 180° F internal temperature. Chef's Prime™ loin roasts were found to be "major" sources of vitamin B-6, thiamin, zinc, and selenium and a "good" source of iron.

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

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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 re-formed 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 prod-

uct 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.

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 pre-weighed (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 subcutane-

ous 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.

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.

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.

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).

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 commi-nuted 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 re-structuring 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 result-ing 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 com-posed 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 tech-nology 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 desir-able sensory and textural attributes which were equal to or better than the intact boneless pork chop control. Scan-ning 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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Pharmacological Levels of Zinc in Nursery Diets - A Review

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Zinc plays significant roles in pig nutrition and health. A zinc deficiency is manifested by skin lesions known as parakeratosis; poor feed intake; slow growth; diarrhea; and atrophy of the thymus, a gland important in immuno-logical competence. Zinc ions may in-teract with *E. coli* by inhibiting the ability of *E. coli* to respire and therefore reducing its activity. In addition, recent University of Nebraska research indi-cates that zinc ions cause the organism responsible for swine dysentery (*S. hyodysenteriae*) to produce less toxin. On the other hand, too much zinc in the feed will cause growth depression, ar-thritis, and ultimately death.

Nutritionists typically add 100 to 150 ppm of zinc to nursery diets to meet requirements for growth. Recently there has been interest in feeding nursery pigs diets containing 2,000 to 4,000 ppm of zinc to combat postweaning stress and diarrhea.

A summary of research studies that have evaluated the response of nursery pigs to pharmacological levels of zinc is presented in Table 1. Added zinc levels ranged from 2,400 to 3,200 ppm. In all cases zinc oxide supplied the supplemental zinc. Percent changes in daily gain, daily feed intake, and feed/gain due to the pharmacological levels of zinc are shown along with the sig-nificance level.

This summary indicates that the response to pharmacological levels of zinc is highly variable. For example, sometimes daily gain was increased by 25% whereas at other times gain was decreased by 28% compared to the con-trol diets containing normal zinc con-centrations. Similar wide ranges in re-sponse to zinc are evident with feed intake. When the incidence of diarrhea was measured, the additional zinc seemed to reduce the frequency of diar-rhea.

The level of copper in the diet does not seem to have a consistent effect on the response to zinc. Large positive responses to zinc were observed at all levels of added copper, but more fre-quent positive responses were observed when dietary copper was low (8 to 22 ppm). Moreover, all the poor responses to zinc were observed when 200 to 250 ppm copper was added to the feed.

These results indicate that the de-cision to use pharmacological levels of zinc in nursery diets should be made on a case-by-case basis. Careful monitor-ing of pig performance when high lev-els of zinc are added to feed is war-ranted to be sure the right conditions exist for a response. Unfortunately, it is currently not possible to describe the conditions under which a positive re-sponse to extra zinc is likely.