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Summary and Implications

Automated mechanical systems are being utilized by the pork industry to efficiently and economically recover meat remaining on bones after fabrication. The recovered meat, referred to as pork trim-finely textured (PTFT), has unique properties which must be understood to best use this lean meat source. This research characterized the chemical and physical properties of PTFT, determined incorporation levels in ground pork and studied the storage and shelf-life-stability of products containing PTFT. Chemical and physical properties of PTFT were compared to knife trimmed meat (KT) and 80 percent lean ground pork (GP). PTFT had higher iron, calcium, total pigment and cholesterol than GP or KT. Moisture and fat content of PTFT did not differ from GP. When PTFT (0,

5, 10 and 15 percent) was incorporated into ground pork patties (10 percent and 20 percent fat), redness and sensory juiciness increased and hardness and cohesiveness decreased at all levels of incorporation. Storage stability of patties containing up to 15 percent PTFT displayed for four days under retail conditions were not affected by PTFT as measured by lipid oxidation, microbial counts and pH. PTFT obtained by mechanical recovery appears to be an exceptional substitute for pork trim in ground pork formulations. PTFT does not negatively influence, and may enhance, the attributes of ground pork when added below 15 percent. Utilization of PTFT contributes to the profitability of the pork industry which is already recognizing the benefits of mechanical recovery due to a reduction in repetitive motion syndrome, which is typically associated with knife trimming.

Introduction

Automated systems to mechanically remove meat from bones after fabrication are being utilized in the meat industry. The machines are advantageous because they are replacing hand trimming of bones with a knife, which has caused a high incidence of repetitive motion trauma among packing plant employees in the past. The machines improve profitability, are more economical and more efficient. The mechanical systems are often referred to as Advanced Meat Recovery Systems (AMRS). One mechanism for recovering meat from bones utilizes a hydraulic piston in a perforated chamber. This machine compacts the bones without crushing or breaking, and causes the meat to be "squeezed" from the bones. These type of machines operate on the basis of different flow properties of meat and bone. At the pressures utilized by the machine, first meat flows out of the holes in the chamber, followed by fat and some connective tissue, leaving the compacted bones within the chamber. In the final phase of meat recovery, the meat passes through a desinewing machine to remove connective tissue. Due to the strong physical forces placed upon the meat and its subsequent passage through very small holes (~1.3 mm), the recovered meat has unique properties. For example, the texture is very fine, similar to finely ground pork, which may allow the recovered meat to alter texture in other products. The recovered meat may be applicable in altering texture of low fat products which tend to have undesirable texture. Mechanically recovered meats reportedly have elevated iron and increased pigment. The total pigment may enhance the color of products it is incorporated within, but high-pigment and iron content can contribute to storage stability by catalyzing lipid oxidation.

To optimize the use of this mechanically recovered meat, the physical and chemical properties must be understood. No published data is available concerning meat from the particular recovery system used in this study (Protecon TL60/Baader 605 Lean Separator). Therefore, the objectives of this study were: (1) characterize the pork from AMRS, (2) incorporate the recovered meat into ground pork formulations to determine usage levels and (3) study storage stability of pork products containing meat from AMRS.

Materials and Methods

Characterization

Untrimmed pork bones (vertebrae, neckbones, aitch, hip and scapula) were processed by a Protecon TL60 followed by a Baader 605 Lean Separator at a commercial meat plant to remove tissue from bone. The recovered meat was referred to as pork trim-finely textured (PTFT). Unprocessed bones were collected to be knife trimmed of meat at a later time. The knife trimmed meat (KT) and 80 percent lean, fresh-ground pork (GP) were used for comparison to PTFT. Analyses of these raw materials included proximate composition, cholesterol, calcium, iron, non-heme iron, total pigment, pH, expressible moisture and total collagen. Data were analyzed as a completely random design with three replications. Significance was reported at $P<0.05$.

Incorporation into ground pork

PTFT was incorporated into ground pork patties according to a 2 x 4 factorial treatment design: 10 percent or 20 percent fat and 0, 5, 10 or 15 percent PTFT. Appropriate amounts of raw materials (lean pork trim from picnic cushions, fat trim from bellies and PTFT from a commercial processor) were mixed for five minutes and ground through a 3/16 inch plate. Patties (4 oz.) were machine-formed, overwrapped on plastic foam trays with PVC film and stored under retail conditions (1076 lux light, $4^{o}C$) for six days. The remaining patties were packed in double polyethylene bags and frozen at $-35^{o}C$.

Color of fresh patties was evaluated daily by collecting reflectance readings to calculate metmyoglobin formation and L* (lightness), a* (redness) and b* (yellowness) values over six days of storage. Frozen patties were cooked from frozen to $72^{o}C$ to calculate percent cook loss, change in patty thickness and diameter. Texture of cooked patties was determined using two-cycle compression to calculate hardness, springiness, cohesiveness and chewiness. A sensory acceptance panel evaluated cooked patties on an eight-point hedonic scale for flavor, texture, juiciness and overall acceptability. The experiment was conducted as a randomized complete block design replicated three times. Significance was reported at $P<0.05$.

Shelf stability

PTFT was incorporated into ground pork according to the same treatment design, manufacturing methods and packaging methods described above. On days zero, two and four of fresh retail display, patties were evaluated for color (as described above), lipid oxidation reported as thiobarbituric acid reactive substances (TBARS), pH,

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aerobic plate counts (APC) and coliforms. Sensory juiciness, flavor and overall acceptability was determined by an experienced sensory acceptance panel (n=50) using an eight-point hedonic scale. Frozen patties were evaluated on weeks zero, four, eight and 12 for lipid oxidation only. The experimental design was a randomized complete block design replicated three times with data analyzed according to repeated measures techniques. Significance was reported at P<0.05.

Table 1. Characterization of pork trim-finely textured (PTFT), knife trim pork (KT) and ground pork (GP)

	Treatment			
Variable	PTFT	Knife Trim	Ground Pork	SEM‡
Moisture (%)	65.81	67.01	64.33	0.92
Fat (%)	18.94	16.19	18.44	1.28
Protein (%)	15.38^{a}	17.24^{ab}	18.04^{b}	0.59
Ash (%)	1.14^{b}	0.93^{a}	0.92^{a}	0.05
Cholesterol (mg/100g meat)	101.67^{c}	72.33^{b}	62.33^{a}	2.49
Calcium (mg/100g meat)	107.50^{c}	26.77^{b}	6.12^{a}	5.53
Total Iron (mg/100g meat)	3.24^{b}	1.11^{a}	1.20^{a}	0.10
Nonheme iron (µg/g meat)	5.96^{b}	2.46^{a}	4.07^{ab}	0.68
pH	6.39^{b}	6.47^{b}	6.12^{a}	0.03
Expressible moisture (%)	32.33^{b}	30.46^{b}	27.77^{a}	0.62
Total pigment (mg/g meat)	5.87^{b}	2.41^{a}	2.16^{a}	0.18
Total collagen (mg/g meat)	5.34^{a}	12.85^{b}	11.58^{b}	0.49

‡Standard error of the mean.
abcMeans within a row with different superscripts are different (P<0.05).

Results and Discussion

The fat and moisture content of PTFT (Table 1) did not differ (P>0.05) from GP, which may indicate PTFT could be a useful substitute for 20 percent fat trimmings commonly utilized in ground and processed meat formulations. The composition of mechanically recovered meats has varied, based on the specific recovery process, bone type, species and amount of lean attached before processing. The ash content was higher for PTFT compared to KT and GP which may indicate presence of very small bone particles. PTFT had a higher calcium content than GP or KT (P<0.05) but was well below the USDA allowable limit of 150 mg/100 grams meat. The higher (P<0.05) cholesterol content of PTFT versus KT or GP may be due to the expression of blood and marrow cells from the soft interior of the bone during the recovery process. Blood provides a transport pathway for cholesterol. The effect of PTFT cholesterol content on cholesterol in a final product would be minimal, due to the low usage levels commonly practiced in industry with meat from AMR. Total iron was higher for PTFT versus GP and KT (P<0.05). The majority of the iron was in the heme form as determined by difference using the nonheme values. The higher total iron may be attributed mostly to incorporation of the oxygen transporting heme protein, or hemoglobin, when pressure exerted on bones during recovery forces the release of iron-containing bone fluids through the porous bone structure. Iron alone, and in the form of heme pigments and non-heme iron, have been implicated as catalysts in lipid oxidation which may contribute to reduced shelf life and stability of mechanically recovered meats.

The higher total pigment of PTFT compared to GP and KT is likely due to incorporation of heme pigments, specifically hemoglobin, from the bone soft interior. The color intensity of mechanically recovered meat may provide a desirable benefit to certain prod-

Table 2. Fat and PTFT main effects on ground pork patty proximate composition, cook yield, cook dimensions, texture and sensory acceptability

	Fat			PTFT				
Variable	10%	20%	SEM‡	0%	5%	10%	15%	SEM‡
Fat	8.62	17.88*	0.38	13.21	13.16	13.26	13.35	0.43
Moisture	73.32	65.89*	0.40	69.40	69.66	69.76	69.62	0.45
Protein	19.10	17.12*	0.13	17.88	18.34	18.19	18.05	0.19
Ash	1.10	0.98*	0.02	1.05	1.05	1.01	1.05	0.02
Expressible Moisture (%)	34.77	35.44	0.50	36.49	34.74	34.90	34.25	0.80
Cook yield	73.50	73.07	0.50	72.69	73.48	73.70	73.34	0.73
Change in diameter (%)	20.29	19.69	1.85	18.29	20.62	19.69	21.32	2.31
Change in thickness (%)	8.31	6.94	0.94	6.44	8.48	6.18	9.39	1.41
Hardness (N/g)	13.12	11.05*	0.32	13.11^{a}	11.70^{b}	12.40^{ab}	11.14^{b}	0.48
Cohesiveness (unitless)	0.59	0.52*	0.02	0.58^{a}	0.55^{b}	0.55^{b}	0.54^{b}	0.02
Springiness (mm)	22.92	21.08*	0.22	22.33	21.72	22.11	21.83	0.33
Chewiness (J/g)	0.17	0.12*	0.02	0.17^{a}	0.14^{b}	0.15^{ab}	0.13^{b}	0.02
Texture	5.44	5.42	0.11	5.20	5.48	5.66	5.36	0.16
Juiciness	5.13	5.46*	0.09	4.90^{a}	5.32^{b}	5.54^{b}	5.42^{b}	0.14
Flavor	5.07	5.06	0.09	4.79	5.08	5.28	5.07	0.14
Overall Acceptability	5.18	5.24	0.10	4.89	5.28	5.46	5.21	0.15

‡Standard error of the mean.
*Means in a row within fat level are different (P<0.05).
abMeans in a row within PTFT level with different superscripts are different (P<0.05).

Table 3. Main effect of day on sensory acceptance and color of ground pork patties

	Day				
	0	2	4	SEM‡	Effect[a]
Sensory acceptance					
Juicy	5.23	5.07	5.07	0.05	L
Flavor	4.97	4.90	4.78	0.05	L
Overall acceptability	5.00	4.89	4.80	0.04	L
Color					
L* (lightness)	57.67	56.01	55.43	0.18	Q
a* (redness)	30.79	25.68	20.74	0.24	L
b* (yellowness)	21.64	19.29	17.28	0.12	L
Metmyoglobin	24.62	30.63	39.83	0.56	Q

‡Standard error of the mean.
[a]L=linear and Q=quadratic (P<0.05).

ucts in terms of enhanced consumer perception, but could cause concern in light-colored products, such as white sausage. The collagen content, an indication of connective tissue, was lower in PTFT than GP or KT (P<0.05). The low collagen value of PTFT is an important attribute which will not limit usage levels in other processed products. The pH of PTFT was similar to KT (P>0.05) and both were higher than GP (P<0.05). The high pH of some other mechanically recovered meats has been attributed to bone marrow, which has a pH of 6.0 - 7.0. The higher pH did not contribute favorably to expressible moisture, as moisture loss was higher for PTFT and KT versus GP (P<0.05). The higher expressible moisture of PTFT may be a result of the small particle size created during the recovery process which increases the overall surface area and may offset the moisture retention possibilities normally related to high pH.

When PTFT was incorporated into ground pork patties, it did not affect (P>0.05) moisture, fat, protein or ash which illustrates PTFT can be added up to 15 percent without significantly altering patty proximate composition (Table 2). PTFT did not affect cook yield, cooked patty dimensions or springiness of ground pork patties (P<0.05). Addition of PTFT resulted in a patty that was generally softer, less cohesive and less chewy (P<0.05) than 0 percent PTFT patties. Other research on mechanically recovered meat has shown levels of addition above 15 percent created a too-soft ground product. The 10 percent fat patties were harder, chewier, more springy and more cohesive (P<0.05) than the 20 percent fat patties, but PTFT had no effect on texture of the low-fat formulation as hypothesized. Expressible moisture of raw patties was not affected by PTFT (P>0.05) despite PTFT alone displaying greater expressible moisture than 80 percent lean ground pork (Table 1). Texture rated by a sensory acceptance panel was not affected by PTFT or fat. Panelists rated the juiciness of product containing any level of PTFT as more desirable than zero percent addition. Neither flavor nor overall acceptability of patties were affected by fat or PTFT (P>0.05). Patties became redder and darker (P<0.05) with PTFT addition, but over days of storage, PTFT did not affect patty color (data not shown). Surface metmyoglobin was not affected by fat or PTFT (P>0.05; data not shown). Metmyoglobin is the brown-gray pigment in meat considered undesirable by consumers.

In the study conducted to determine shelf stability, color and sensory acceptance, data for the main effects of PTFT and fat in ground pork patties was similar to the results of the prior study, so only day effect is reported and discussed for these attributes (Table 3). The sensory attributes of juiciness, flavor and overall acceptability declined (P<0.05) during retail display. The patties became darker, less red, less yellow and had increased metmyoglobin content during the display period. Lipid oxidation, as measured by TBARS, was not affected by PTFT or fat (P>0.05), but increased (P<0.05) during days of retail display (Table 4). TBARS values on day four remained below 1 mg malonaldehyde/kg meat, which is considered the point of unacceptance for raw product. Lipid oxidation of frozen patties was not affected by PTFT (P>0.05) but was explained by a fat x week interaction (P<0.05; data not shown). Lipid oxidation of 10 percent fat patties decreased more during 12 weeks of storage than 20 percent fat

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Table 4. Main effects of fat, pork trim-finely textured (PTFT) and day on lipid oxidation, pH, aerobic plate count, and coliform data for ground pork patties

	Fat			PTFT						Day				
	10%	20%	SEM‡	0%	5%	10%	15%	SEM‡	Effect[a]	0	2	4	SEM‡	Effect[a]
Lipid Oxidation (TBARS[b])	0.81*	0.66	0.03	0.75	0.72	0.69	0.77	0.04	NS	0.57	0.69	0.94	0.04	L
pH	6.08	6.08	0.01	6.08	6.09	6.07	6.09	0.01	NS	6.05	6.13	3.06	0.01	Q
Aerobic Plate Count (log_{10} cfu/g)	6.63	6.61	0.04	6.63	6.62	6.66	6.58	0.05	NS	5.32	6.66	7.87	0.05	L
Coliforms (log_{10} cfu/g)	2.90	2.86	0.08	2.82	2.87	2.90	2.93	0.11	NS	2.32	2.65	3.68	0.10	Q

‡Standard error of the mean.
[a]NS=not significant, L=linear and Q=quadratic (P<0.05).
[b]TBARS reported as mg malonaldehyde/kg meat.
*Means in a row within fat level are different (P<0.05).

patties. However, the rate of change was not greater than 0.2 mg/kg meat. The pH of the patties was not affected by PTFT, fat or day (P>0.05; Table 4). Aerobic plate count and coliforms were not affected by PTFT or fat (P>0.05). Both microbial indicators increased during retail display but remained at acceptable levels.

Conclusions

The inherent properties of pork trim-finely textured (PTFT) do not differ dramatically from knife-trimmed pork for most attributes related to functionality, making PTFT a potential economical ingredient to replace lean trimmings in ground or emulsified products. When PTFT was incorporated into ground pork patties, juiciness and color improved. The higher total pigment content of PTFT increased redness of patties, which may increase consumer appeal for ground pork by enhancing the desired bright red color. PTFT had no adverse effect on fresh pork lipid oxidation, microbial counts, color, sensory acceptability or frozen ground pork lipid oxidation during storage. Therefore, storage stability does not appear to be a concern when PTFT was incorporated up to 15 percent in ground pork.

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