RESTRUCTURING TECHNOLOGY FOR THE

MEAT INDUSTRY IN TAIWAN, R.O.C,

by

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A REPORT

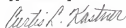submitted in partial fulfillment of the

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RESTRUCTURING TECHNOLOGY FOR THE
MEAT INDUSTRY IN TAIWAN

INTRODUCTION

Taiwan Province of the Republic of China has a land
area of 3.6 million hectares and the population is about 20
million. The major food of Taiwanese is rice but during the
past two decades Taiwan livestock production has had a
steady growth. While the production of hogs, chickens, milk
and hen eggs has shown large increases, cattle and goat
production decreased during the 1976-1986 period (Table 1).

Table 1. Production of principle livestock products

Livestock	Unit[1]	1966	1976	1986
Cattle	1000 mt	5	11	4
Hogs	1000 mt	272	522	1,054
Goats	1000 mt	0.9	1.6	0.6
Chickens	1000 Head	21,771	64,776	155,917
Ducks	1000 Head	11,100	20,091	34,347
Geese	1000 Head	3,029	2,705	3,266
Turkeys	1000 Head	899	1,377	1,383
Milk	1000 mt	14	45	110
Duck Eggs	1000	372,798	478,849	429,246
Hen Eggs	1000	271,830	1,209,968	3,339,487

[1]mt = metric ton.   Sources: Industry of Free China,1987.

Being an island not richly endowed with natural resources, Taiwan has to rely on external trade to promote agricultural and economic development. Partially supplemented with imported products, Taiwan agriculture has been able to make more foods available per capita although the population has grown rapidly during the post-war (Second World War) period. The general trend in consumption is toward less rice, constant amount of flour, much less starchy roots (including sweet potato and cassava), but more vegetables, fruits, red meats, dairy products, eggs, poultry and fish.

Pork is the major source of red meat in Taiwan. Per capita pork consumption in 1984 was about the same amount as in the U.S.A., but lamb or poultry consumption was about 50 % and beef about 3 % of the American consumption (Table 2). Taiwan imported 53,000 metric tons (mts) of livestock and poultry products but exported 86,000 mts of pork in 1986.

Table 2. Comparison of meat consumption between
         Taiwan and U.S.A. in 1984

Livestock	Taiwan	U.S.A.	% Taiwan/U.S.A.
Pork	31.1 Kg	29.8 Kg	104
Beef	1.62 Kg	48.3 Kg	3.3
Lamb	0.37 Kg	0.77 Kg	48
Poultry	18.6 Kg	30.7 Kg	61

Processed meat is estimated to be about 10 % of the meat consumed in Taiwan, with 80 % being traditional Chinese style meat products, such as dried pork floss, dried pork slices, canned meats, sausages, cured ham and meat balls. Traditional processing methods for Chinese style meat products are highly dependent on labor intensive processes that are difficult to control and adapt to mass production.

The demands for more convenient and uniform processed meat products are increasing in accordance with the economic development of Taiwan. Therefore restructured meat technologies that meet market demands for the Taiwanese market are covered in detail in this report.

Restructuring is a manufacturing step by which various carcass parts and trimmings are converted by mechanical and chemical manipulation into newly restructured forms. Restructuring technology is not new and has historically been used to manufacture sausages. However, the new concept of restructuring includes a greater variety of products. Any skeletal muscle can be restructured into a new group of consumer-ready meat products such as turkey ham, roast beef, snack sticks, beef steak, diced beef, chicken logs, corned beef logs, cured ham, chicken nuggets, pork nuggets, veal steak, chicken sticks, beef fingers and chicken patties.

Reduction of particle size is usually the first step

in the restructuring process. Particle reduction methods include sectioning, chunking, grinding, slicing, flaking and chopping. Sectioning involves the separation of entire muscles by seaming. Chunking is accomplished by grinders, dicers and bowl choppers to reduce particle size to 2-4 oz. Grinding involves the use of plate grinders with varying plate sizes and configurations. In flaking, the meat is forced against stationary precision-honed shearing heads, resulting in uniform-sized flakes of meat. The size and shape of the meat " flakes " may be adjusted by the size of the various cutting heads, the impeller speed and the temperature of the raw materials. Ideal temperatures of meats for flaking have been reported by several investigators (Popenhagen et al., 1973; Mandigo, 1975; Chesney et al., 1978; Huffman, 1979). Research at the Army Natick Laboratories indicates that meat temperatures in the range of $-4^{\circ}C$ to $4^{\circ}C$ are optimal to produce desired texture (ABMPS 1981). Slicing involves the use of various types of slicers. Chopping is accomplished by bowl choppers to reduce particle size.

Development of the flaking and forming technology resulted in the first important production process for restructured meats. When price is the primary consideration, the combination of finely flaked trimmings with either chunked or more coarsely flaked meats is a possible choice.

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Although the process of sectioning and forming has been largely replaced by chunking and forming, the sectioning and forming process is still used by some ham producers. Because the muscles themselves are never reduced to smaller pieces, the finished product retains the appearance and texture of whole muscle products. The sectioning and forming process finds use in the massaging and forming of smaller units of meat musculature such as the tenderloin (Secrist, 1987).

A company increases profit from the marketing of secondary carcass parts and trimmings by transforming the relatively low-value parts into products that have increased market value. Consumers can purchase products with characteristics readily identifiable with high value meat products at substantial savings. The restructuring processes transform meat into any shape and size desired, thus making possible various avenues in which to market a product. The closely controlled portion weights of restructured meat makes cost accounting an exact procedure as well as the accurate prediction of cooked yields and servings. The flaked and chunked meat can be " programmed " as required for fat content and nutrient fortification when the nutrient value of is of concern (Secrist, 1987).

Some problems of restructuring still require study. For example, the mechanics involved in the flaking process are disruptive to the cellular structure of meat tissues.

The high rotational speed required of the impeller to place the whirling meat pieces into contact with the stationary knives of the cutting head during flaking creates a tremendous movement of air at the cut surfaces. Oxygenation of the freshly exposed cellular meat mass begins an oxidation chain reaction. Critical to the producer are the control of process temperatures and timely movement of product through the system to final freezer storage. The incorporation of carbon dioxide " snow " during the flaking process and use of packaging materials with oxygen- and moisture- barrier properties has proven beneficial to product flavor and color. Reducing the impact of connective tissue is probably the major economical concern to the producer of chunked and formed products. Retail marketing of the flaked and chunked formed meats has been hampered because they are designed to be retailed as a frozen product that often makes them unattractive to retailers who must satisfy customers accustomed to selecting their meat purchases from chilled meat choices. With further improvements in the binding methods for chunked and formed meats, the day may not be far away when these products can be marketed along with the solid muscle and sectioned and formed meats in chilled meat display areas (Secrist, 1987).

Meat Production, Marketing, Processing and Consumption in
Taiwan, R.O.C.

Swine Production, Marketing and Processing

Taiwan swine production occurs largely in the
southwest plain which has the largest rural area. Swine
housing is mostly open type confinement that provides
shade and ventilation during the summer and shelter during
the winter. Most production systems involve farrow to
finish. It is a common practice to castrate male pigs for
fattening. Swine production in Taiwan is becoming larger
and more intensified (Table 3). This trend has increased
the demand for imports of concentrate feedstuffs (Table 4).
A soybean-corn mixture is the major ration for swine.

Most producers utilize three way crossbreeding
programs. Breed registration records show that Landrace
(L), Large White (Y), Duroc (D) and Hampshire (H) are the
primary breeds in Taiwan (Table 5). Female genotypes are
selected for reproductive performance, prolificacy and
mothering ability, whereas sire genotypes are selected for
growth rate, muscling and body fat.

Table 3. Swine production trends

Year	Farms	Total	Head numbers Breeding	Finishing
1977	293,121	3,760,475	336,124	3,424,351
1982	116,581	5,182,487	532,808	4,649,679
1987	67,889	7,175,733	776,116	6,399,614

Source: Journal of Grains and Live Stock.

Table 4. Quantities[1] of grains imported by Taiwan

Year	Wheat	Barley	Corn	Soybean	Sorghum
1965	376,608	$-$	44,207	161,400	$-$
1975	542,905	163,334	1,388,461	827,437	152,095
1985	754,657	337,047	3,017,336	1,469,320	564,410

Source: Journal of Grains and Live Stock.
[1]metric tons

Table 5. Performance records of predominate swine
breeds in 1986

Breed	ADG (Kg)	Feed/Gain	Back fat thickness Avg (Cm)	110 Kg age (days)
Duroc	0.88	2.53	2.21	174
Yorkshire	0.86	2.62	2.30	177
Landrace	0.84	2.63	2.20	176
Hampshire	0.85	2.45	2.19	186

Source: Cyanamid Ranch.

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Most market hogs in Taiwan are marketed on a live weight basis. Only part of the hogs produced by the Taiwan Sugar Corporation are marketed on carcass weight and grade basis. Price differentials for different grades often are significant. The hogs can be marketed either through local dealers, the cooperative marketing channel, auction stations, pork retailers or meat packing plants. Approximately 7.6 million hogs were slaughtered in 1985, among which about 2.2 million hogs were slaughtered for export. Carcass grades actually are "index" values based on backfat measurements (11th rib backfat thickness), hot carcass weight and a subjective conformation judgement (Table 6). Price adjustments are made for thick-muscled or light-muscled hogs as well as for unacceptable (PSE) carcass quality. Carcasses must be in an acceptable backfat thickness and weight range to have a high index. Price for hogs with an index of 100 is the same as the average hog price of domestic auction stations. Significant price differences provide economic incentives to producers to market leaner hogs of acceptable quality (Table 7).

Japan, a net importer of pork, imports from Republic of China, Denmark, Canada and U. S. A. (Table 8). The amount of pork exported from Taiwan, Republic of China is increasing and has exceeded that from Denmark since 1986.

Table 6. Price indexes of Taiwan hog carcass adjusted by
conformation judgement

Grade	Carcass weight(Kg)	Backfat thickness(Cm)	1	2	3	4	5	Ex
A	72.0-77.5	0.4-1.3						
	77.6-83.0	0.5-1.4						
	83.1-88.5	0.7-1.5	119	113	104	96	87	80
	88.6-94.0	0.7-1.6						
B	72.0-77.5	1.4-1.6						
	77.6-83.0	1.5-1.8						
	83.1-88.5	1.6-1.9	117	111	100	96	86	80
	88.6-94.0	1.7-2.1						
C	72.0-77.5	1.7-2.0						
	77.6-83.0	1.9-2.2						
	83.1-88.5	2.0-2.3		109	101	95	85	80
	88.6-94.0	2.2-2.5						
D	72.0-77.5	2.1-2.3						
	77.6-83.0	2.3-2.5						
	83.1-88.5	2.4-2.7		106	100	94	84	80
	88.6-94.0	2.6-2.9						
E	72.0-77.5	2.4-2.8						
	77.6-83.0	2.6-3.0						
	83.1-88.5	2.8-3.1			99	91	83	80
	88.6-94.0	3.0-3.3						
F	72.0-77.5	2.9-3.2						
	77.6-83.0	3.1-3.4						
	83.1-88.5	3.2-3.5				90	82	80
	88.6-94.0	3.4-3.6						

Source: Taiwan Meat Development Foundation, Taipei.

Table 7. Taiwan mean hog carcass measurements

Year	Average carcass weight (kg)	11th rib backfat thickness(cm)	% Excluded from export
1980	78.9	2.40	27
1981	79.8	2.36	22
1982	79.8	2.33	21
1983	80.5	2.28	19
1984	81.1	2.13	9
1985	81.9	1.95	9
1986	82.5	1.89	9

Source: Cyanamid Ranch.

Table 8. Pork supply of Japan

Unit: mt

Year	Local production	Imported pork	Imported from			
			U.S.A.	Canada	Taiwan	Denmark
1980	1475684	108158	29745	30019	16669	29220
1981	1395801	183629	39134	42599	19783	72270
1982	1427371	141086	32755	43570	19688	18833
1983	1428804	166253	35410	41836	33084	17680
1984	1424204	195609	22930	29581	50721	75098
1985	1531914	190223	11904	21926	67797	77402
1986	1550442	207719	14729	22448	83573	78092

Source: Taiwan Grain and Feeds Development Foundation, Taipei.

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Warm, fresh pork is the predominant meat in Taiwan.
Most hogs are slaughtered utilizing non-electrical
stunning, although electrical stunning was introduced from
the U.S.A. in 1968, only hogs slaughtered for export and
small numbers of domestically consumed hogs are
electrically stunned. Retailers have strong negative
attitudes toward pork from electrically stunned carcasses,
because their customers usually complain about the PSE
pork that seldom occurs with non-electrically stunned hogs.
Hogs for domestic use are mostly slaughtered around 3 AM
and then carried to a meat vendor's stand under
environmental temperature (15-25 ^{o}C). Most pork carcasses
are stored for 2 to 3 hrs postmortem, then hot-boned and
sold as warm, fresh pork. Retailers make primal and retail
cuts according to their customer's demand. Most
subcutaneous fat is trimmed but the belly is sold with skin
on. Unchilled fresh pork is packaged in a PVC bag after
being sold. Pork is usually sold within 6 hrs postmortem
and well cooked to over 100 ^{o}C before it is served.

Chilled or frozen pork is produced at commercial meat
packing plants. The slaughtering procedure is similar to
that in commercial slaughter plants of the U.S.A. except
evisceration is done before skinning. The earlier that
evisceration is done, the higher the quality of the offal.
Most of the chilled or frozen pork is exported to Japan.
Because the meat quality and trimming specifications meet

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the market demands in Japan, the amount of exported pork is increasing (Table 9).

Table 9. The quantity and value of exported Taiwan pork

Year	Quantity (mt)	Value US$1000
1980	17,074	62,504
1981	19,701	76,526
1982	20,084	72,789
1983	33,863	124,304
1984	52,111	183,248
1985	68,762	249,873
1986	86,479	408,007

Source: Journal of Grains and Live Stock.

Four lean cuts of pork produced in Taiwan are those normally required by the Japanese market. The higher value parts such as the fillet, loin, ham and butt shoulder are well trimmed and netted as semi-manufactured products to be exported to Japan according to the Japanese custom rate.

Most bellies, picnic shoulders and trimmings have to be sold in the domestic market. These are the current sources of chilled or frozen small packaged pork sold in modern supermarkets. The more pork exported, the more chilled pork needs to be sold in the domestic market. Most consumers prefer warm, fresh pork over chilled pork. Refrigerated systems are not well established all over the country due to the high cost of energy. Temperature

fluctuation during marketing makes the meat quality worse than the warm fresh meat. Restructured meat processing thus becomes a very important technology to process the raw material into high value, processed meats.

Processed meat consumption is about 10 % of the fresh meat. The total processed meat production in Taiwan was about 45,000 mts in 1986. Traditional Chinese style sausage, dry pork floss, dry pork slices, meat balls and canned pork are the most popular products.

As the economy improved, consumers have increased the demand for pork chops. Hospitals, military, institutions and school meals need chops that are uniform in appearance. Modern supermarkets are increasing offerings of western-style processed meat products such as pressed ham, bacon, frankfurters, meat patties, smoked loin and breaded pork chops and nuggets. The fast food chain stores such as Mc Donald's, Wendy's, Hardee's, Arby's etc. as well as Japanese and Taiwanese fast food restaurants have increased tremendously in recent years. Therefore, the demand for convenient prepared meat products processed by restructuring technology appears promising for the Taiwanese market.

Beef Production, Marketing and processing

While the beef cattle production is quantitatively rather minor in Taiwan, frozen beef imports are increasing due to the increasing consumption (Table 10). Along with the rapid industrialization of Taiwan's economy, people with higher income consume more beef and poultry but less pork (Table 11).

Hot-boned fresh beef and imported frozen beef are the two major items in the Taiwan market. Frozen beef is much cheaper than domestically produced fresh beef. Most beef cattle are fed in confinement with seasonal farm by-products and are not well finished with concentrate rations. Market weight ranges from 300 Kg to 500 Kg. Cattle are usually marketed through cattle shippers and are priced on a live weight basis. There is no beef carcass grading system in Taiwan although efforts are being made to initiate one. Beef production is decreasing due to the competitive price of imported frozen beef. The beef industry of Taiwan needs to develop intermediate value beef products . Therefore, the restructuring technology used in the production of intermediate value beef products will be covered in detail.

Table 10. Domestic cattle slaughter and frozen beef import in Taiwan

| Year | Domestic cattle slaughtered | | Beef imports | |
	Head	Carcass weight(mt)	Quantity(mt)	US $1000
1979	46,880	8,518	12,051	24,932
1980	32,520	5,499	10,927	30,926
1981	30,758	5,190	17,275	48,831
1982	33,282	5,740	19,762	52,554
1983	37,562	6,619	23,083	63,085
1984	33,569	6,482	24,069	65,782
1985	24,172	4,351	27,347	70,371

Source: Taiwan Sugar.

Table 11. Meat consumption per capita of Taiwan

| Year | Total (Kg) | Pork | | Beef | | Lamb | | Poultry | |
		Kg	%	Kg	%	Kg	%	Kg	%
1955	16.31	14.56	89.27	0.3	1.84	0.04	0.25	1.41	8.15
1965	19.21	16.77	87.30	0.39	2.03	0.06	0.31	1.99	10.4
1975	26.98	17.51	64.90	0.94	3.48	0.17	0.63	8.36	31.0
1985	54.30	34.23	63.04	1.66	3.06	0.39	1.72	18.0	33.2

Source: Council of Agriculture, Taipei, Taiwan, R.O.C.

Raw Materials

A wide range of raw materials may be used to make restructured meats. Selection and utilization of raw materials determines the ultimate composition and texture of the finished product. Raw material cost will also be reflected in finished product cost. All raw materials must be as fresh as possible. The use of aged meat may cause a number of problems, including bacterial, enzymatic and oxidative degradation which result in off-flavors. Color may deteriorate rapidly. A workable time schedule would be to debone a carcass within 24 hrs postmortem, and then to use the materials in a further processed product within two days postmortem in the case of pork and within seven days postmortem in the case of beef and lamb. This suggested schedule assumes that the meat is maintained at 29 ^{O}F to 36 ^{O}F (NLSMB, 1985).

Hot boning may decrease processing costs, improve product yields, and allow the use of pre-rigor meat which can facilitate particle binding in the restructuring process (Kastner, 1982). Hot-boned, pre-rigor meat, as opposed to post-rigor meat, has several advantages, including superior extractability of myosin (Solomon et al., 1980). Hot boning resulted in more acceptable raw steaks in terms of visible fat appearance even though

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extractable fat levels were similar to conventionally boned counterparts. Hot boning also showed superior textural appearance, possibly superior color, and in cooked beef rolls, a higher cooking yield.

Just because a carcass is processed sooner postmortem than the usual practice does not mean that the muscle is in a prerigor condition. In fact, some hot- processing techniques have been designed to avoid processing muscle before the onset of rigor mortis, whereas in others the attempt has been to capitalize on the functional properties of prerigor muscle (Kastner, 1982).

Pre-rigor beef restructured steaks required longer broiling time and lost more fat during broiling, but were similar in moisture loss and total cooked yield compared to steaks made from post-rigor beef. Sensory panel scores of broiled steaks for degree of doneness, flavor, juiciness, texture description or desirability, tenderness or over all palatability were similar whether using pre-rigor or post-rigor beef (Seideman et al., 1982).

Pre-rigor pork muscle has many advantages for cured meat including greater water holding capacity (Hamm, 1973); more soluble protein (Kramlich, 1978); greater rate of cure diffusion and more nitroso pigment content (Arganosa and Henrickson, 1969); improved ham flavor, juiciness, and color (Chow et al., 1986).

The principle disadvantage in the use of hot

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processed, pre-rigor muscle for restructured steaks may be a decreased tenderness due to cold shortening or thaw rigor. However, conditioning sides at near physiological temperatures for a period of 3 - 6 hrs postmortem may alleviate tenderness problems associated with hot processed muscle (Falk et al., 1975). Hot boning used in conjunction with a carcass conditioning period can be successfully incorporated into the processing scheme of restructured beef steaks (Paterson et al., 1987).

Electrically stimulating beef carcass soon after slaughter can speed the onset of rigor mortis, thereby eliminating or minimizing tenderness problems associated with prerigor excision, heat shortening, cold shortening and thaw rigor. Consequently, carcass or muscle conditioning and aging periods used to avoid potential tenderness difficulties associated with rapid hot processing and chilling or prerigor muscle can be eliminated or reduced by using electrical stimulation. However, electrical stimulation may reduce or eliminate the functional advantages that hot-boned, pre-rigor muscle may offer a restructured system (Kastner, 1982).

If restructured steaks are made from pre-rigor beef, a sufficient quantity of salt (over 0.6%) must be added quickly postmortem to maintain a high final pH (5.9 or higher) (Seman et al., 1986). Addition of cryoprotectants improved the maintenance of water holding capacity, gel-

forming ability and protein solubility properties of both salted pre-rigor and post-rigor meats (Park et al., 1987). NaCl and sodium tripolyphosphate were detrimental to color of pre-rigor and conventionally boned pork chops (Marriott et al., 1983). Regardless of the rigor state of the raw materials, the addition of salt during the manufacturing process improved flavor, texture and acceptability and reduced cooking loss of the restructured beef steaks, but color was negatively affected (Huffman et al., 1984). If pre-rigor, pressurized beef is employed in the manufacture of restructured steaks, acceptable texture properties appear obtainable without the use of salt (Berry et al., 1986).

Overabundance of connective tissue results in very poor bind (Schut, 1976). Utilization of chucks in the production of restructured beef products may result in problems due to the amount and type of connective tissue associated with the muscles in that wholesale cut. Removing some of the heavy connective tissue from beef chucks before chunking and forming is necessary.

Meat Particle Size Reduction

Methods used for size reduction includes sectioning, chunking, slicing, hydroflaking, grinding, flaking, chopping and emulsification. Mechanical deboners and mechanical desinewers not only reduce particle size and

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disrupt the continuity of connective tissue but also selectively remove heavy deposits of connective tissue.

Sectioning

Sectioning involves separation of entire muscles by seaming, a very useful procedure for large muscles such as in the leg, loin and shoulder of pork. Connective tissue residue was not a palatability problem in restructured steaks after trimming excess connective tissue from beef chucks (Booren, 1981 b,c). Both tenderness and connective tissue residue were rated less desirable in sectioned and formed steaks made from the chuck than those from the round. Removing some, but not all of the heavy connective tissue (all visible, surface connective tissue) from beef clods appeared to be worthwhile (Recio, 1986). Even so other methods of reducing the effects of connective tissue may prove fruitful.

Blade Tenderization

Blade tenderization is desirable when producing sectioned and formed steaks from the less tender beef muscle. Blade tenderization improved muscle fiber tenderness and reduced the perception of connective tissue in strip loins and top sirloin butts from bulls (Savell et al., 1982). After 90 days of freezer storage, TBA values were higher for blade-tenderized than for non-tenderized steaks, possibly explained by the fact that cut surfaces were increased and more oxygen was introduced into the

steaks during blade tenderization (Booren et al., 1981b).

Chunking

Meat can be made into chunks with a knife, meat dicer, bowl chopper or coarse grinder plate. Grinder plates with kidney-shaped openings are useful for making chunks with more surface area for the extraction of proteins and thus better reforming ability than chunks made by dicing. Connective tissue is the largest single problem in restructured chunked and formed meat (Field, 1982). Mechanical tenderization of meat before its use in restructured products ensures maximum cell disruption that will ultimately result in superior binding properties (Huffman, 1979). When use of large pieces of meat is necessary to provide a texture or bite similar to that of intact muscle, mechanical needle-tenderizers do not offer a practical solution to the problem of connective tissue in restructured meat product (Secrist, 1982). Even though blade tenderization was not as totally effective as trimming in reducing the undesirable effect of connective tissue, it may be a viable alternative to trimming considering that it is much less labor intensive and it does not reduce yield due to trimming (Flores et al., 1986).

Slicing

Frozen and tempered meat may be sliced on high speed

slicers to reduce particle size, and slicing may be especially useful for tissues that are relatively high in fat. When appropriately blended, slices will give an appearance similar to natural marbling. A specific example of this procedure would be thin slicing of boneless, frozen/tempered blade boston butts for use in a restructured pork chop. Since myoglobin has a high affinity for oxygen at or near the freezing point, a very desirable color can be maintained by thin slicing. Slicing thickness had little effect on the sensory properties of the restructured product (Nobel et al., 1985). Neither cooking time required to reach a given internal temperature nor moisture loss during cooking have been shown to be affected by slice thickness. Slice thickness affected the shear force of cold- and hot-boned beef inside and outside rounds. More energy was required to shear thick than thin slices (Cordray and Huffman, 1984).

Hydroflaking

Hydroflakers are used on frozen, tempered meat to quickly reduce particle size and make frozen meat readily available for use in meat products. The equipment is in effect a heavy-duty slicer (Anon, 1980). This process may be a useful initial step in subdividing frozen blocks for further comminution.

Grinding

Grinding, the most common and widely accepted method

of particle reduction, has been used for years to make tough cuts or low-grade meats acceptable for use. Sharp knives and properly tensioned plates will produce ground meat with a minimum amount of fat smearing. Low temperatures (-2°C to 0°C) help prevent fat smearing and result in better particle definition in a restructured product (Gillett, 1987). Restructured pork products can be manufactured using two distinctly different meat blocks. The fatter meats or meats with higher amounts of connective tissue can be finely ground, whereas the leaner meats can be ground through a coarser plate (NLSMB, 1985).

Flaking

Flaking is the procedure of reducing size using the Urschel Comitrol or similar equipment. Particle size is controlled by the size of the openings in the flaker head. Meat subjected to this method should be frozen and tempered to assure flakes of predictable size. Smaller flakes produce lower shear values, higher tenderness values, and smaller cooking loss than larger flakes when utilized in restructured pork products (Chesney et al., 1978), and using a 50:50 blend of coarse and fine particles will give higher scores for juiciness, tenderness and acceptability (Popenhagen et al., 1978). Restructured beef steaks from cows were more tender if a higher portion of fine flakes (0.635 cm) was used rather than medium (1.25 cm) or coarse flakes (1.905 cm) (Durland et al., 1982). For flaking, the

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fatter meats should be tempered to about 3.3 °C and the leaner meats to -4.4 ° to -3.3 °C. Fine flaking is an excellent way to reduce particle size of raw materials high in fat or connective tissue. Hot-boned raw materials can be passed through the Comitrol with minimal chilling, but there will be considerable fat smearing the raw formed product. If the temperature is too low, a powder will result which can disperse fat in a restructured product.

Several comparisons have been made between the various methods of reducing the meat block (slicing, grinding and flaking) and the resulting particle size. There is better orientation and less squeezing action with flaked meat particles than with ground particles. Cooking yields and bind increased as particle size decreased for flaked pork (Chesney et al., 1978; Field, 1983). Flaking increased product tenderness, texture and flavor of beef round muscles but had no effect on cooking characteristics such as cooking time, moisture losses, total cooking loss, degree of doneness and palatability (Costello et al., 1981).

Chopping

A bowl chopper or silent cutter can be used to reduce particle size to chunks, coarsely chopped or finely chopped material. Chopping is a quick method of reducing particle size, but the resulting particles are less uniform than those produced by grinding. Vacuumized chopping can improve

color and reduce oxidation. Smearing is not likely if the rotating blades are well honed (Gillett, 1987). Since chopping is a batch operation, it may cause severe problems by interrupting a continuous flow production system.

Emulsification

Emulsification is applied to material that has already been blended and ground. In a restructuring process, only a small portion of the total meat block (usually that high in fat or high in connective tissue) is passed through an emulsifier. Emulsification is a common procedure to achieve very uniform particle size reduction in the manufacture of frankfurters and bologna, but it has limited application in the manufacture of restructured fresh pork.

Mechanical Deboning and Desinewing

Trimmings containing large amount of connective tissue can be mechanically desinewed before mixing with other components. Mechanical deboning reduces the particle size of meat, because small sieve sizes are usually employed to remove bone particles. The addition of mechanically separated beef (MSB) to restructured beef products may improve palatability and visual properties since MSB contains high amounts of heme pigments (Field, 1974). MSB can be added to restructured steaks without detrimental effects on sensory characteristics and storage life as compared to textured soy protein or vital wheat gluten (Miller et al., 1986a).

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While steaks containing 15 or 20 % mechanically separated meat (MSM) had mushy interiors, 5 % could be added to reduce cost with no effect on quality, and a 10 % addition actually improved the quality while further reducing cost (Field et al., 1977). MSM yield is affected by such factors as amount of lean and connective tissue removed from the bones, the origin and type of bones, the type of machine and the operating characteristic of machine.

Gillett et al., 1976 described a specially designed head for a Beehive deboner with 0.19 cm perforations, which permitted the removal of almost half of the connective tissue of boneless beef shanks, chucks, plates and pork shoulders. The desinewer improved the palatability of salami by reducing collagen content by 46 %, but a 12.6 % reduction in fat also occurred. Meat desinewed with the 0.19 cm head was superior to meat desinewed through larger sized perforations (Cross et al., 1978). Desinewing has its greatest effect in meat from mature animals where the influence of connective tissue was greatest.The limitation for desinewing probably lies in finding an economical use for product removed by the machines.

Protein Extraction and Binding

The extraction of myofibrillar proteins from meat is influenced by many factors, e.g., the state of rigor

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development in the meat; the ionic environment and the pH of the system; the temperature history of the meat during rigor onset; the temperature of the mixture during extraction; the length of storage; application of high pressure to the system and miscellaneous physical factors such as the duration of extraction, and degree of agitation of the system, the size of meat particles and mixing under vacuum (King and Macfarlane, 1987). Mixing parameters have a dramatic effect on a variety of characteristics of restructured meat systems.

Mixing

The role of mixing is very important in the production of a restructured meat product. The two most important functions for mixing are (1) introduction and homogenization of components and (2) solubilization of proteins through the mechanical action of impact and frictional energies.

Mixing may actually incorporate oxygen into the product. Restructured products exhibit a great variety of oxygen partial pressures close to the surface and, consequently, may have a greater variety of myoglobin forms and colors than regular meat cuts. Mixing under vacuum has resulted in superior scores over nonvacuum but spectrophotometric values indicated less desirable surface colors for vacuum-mixed steaks (Booren et al., 1981b). Booren et al., 1981c found no evidence that vacuum mixing

resulted in decreased rancidity, whereas removing oxygen by vacuum mixing in the absence of added salt resulted in a lower TBA value after 90 days freezer storage. Cooking yields, flavor, juiciness, tenderness and connective tissue residue have not been affected by vacuum. Bind has been shown either to be unaffected or improved by vacuum (Solomon et al., 1980; Macfarlane et al., 1986). Total protein extracted did not increase due to vacuum, but the crude myosin content did.

Subjective scores for color have been shown to be adversely affected by a mixing time of 18 min. compared to 12 or less, but spectrophotometric measures of color indicate no effect of mixing time on color (Booren et al., 1981a). Visual fat appearance was not affected by mixing time but textural appearance was scored finer (p<0.05) after 10 or 15 min. of mixing when compared to 5 min. over all appearance was not affected by mixing time. Indicators of oxidation were not affected by mixing time (Booren et al., 1981c). Cooking time required to reach a similar internal temperature was not related to mixing time (Noble et al., 1985). While mixing time has, at times, been reported as having no effect on cooking yields, several researchers report increased cooked yields with increased mixing times (Durland et al., 1982; Booren et al., 1981a,c; Pepper et al., 1975).

Moisture content has in some cases been shown to be

not different between mixing times, but other researchers have shown intermediate mixing times of 10 or 15 min. to result in lower moisture than either short (5 min.) or long (20 min.) mixing times (Durland et al., 1982; Noble et al., 1985). Fat content of broiled steaks was lower for longer mixing times, but not affected by mixing times in cooked beef rolls (Pepper et al., 1975; Durland et al., 1982; Noble et al., 1985).

Sensory panel values for degree of doneness in broiled steaks were not related to mixing time (Durland et al., 1982; Noble et al., 1985). Flavor has been reported to not be related to mixing time, but some researchers found that flavor improved with increased mixing times (Booren et al., 1981a,c; Durland et al., 1982). Other researchers have found intermediate mixing times to result in superior flavor scores to either short or long mixing times (Noble et al., 1985). Juiciness scores also show varying response to mixing times with no significant effect observed by some workers and others reporting juiciness improved with increased mixing times and still others finding short mixing times superior to long mixing times (Booren et al., 1981a,c; Noble et al., 1985; Durland et al., 1982). Texture desirability scores were reported in one case to be unaffected by mixing time (Durland et al., 1982), but other researchers found some evidence that 20 min. of mixing time exerted an adverse influence on texture as compared to

shorter mixing times (Noble et al., 1985). Texture has been described as more rubbery or tougher as mixing time increased. Tenderness scores as related to mixing time ranged from no significant effect (Booren et al., 1981c) to an adverse effect with increased mixing time (Durland et al., 1982; Noble et al., 1985) to a linear improvement of tenderness with increased mixing time (Booren et al., 1981a).

Tumbling and massaging are popular techniques used for restructured muscle particles or chunks to produce products which resemble intact muscle in textural properties, color and quality. Tumbling imparts mechanical energy to meat chunks to facilitate salt-soluble protein extraction. This occurs when the meat falls from the upper baffles within a rotating drum, resulting in the meat pieces striking each other by the container. Massaging is associated with frictional energy of paddles or meat against meat resulting from a rotating shaft which stirs the product while tumbling is associated with impact and frictional energy (NLSMB, 1985).

Myosin extraction increased linearly with increased mixing time (Solomon et al., 1980). Bind was nonexistent without mixing and improved with mixing time up to 16 min. with no further improvement after 24 min. (Booren et al., 1981c). In flaked meat patties, binding strength increased ($p<0.05$) with an increase in mixing time, but a loss in the

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fibrous appearance of the product was noticed (Macfarlane et al., 1986).

In addition to its protein extraction function, dropping the meat in the tumbler causes the internal structure of the meat to be disrupted, facilitating protein extraction and enhancing the ability of the meat mass to entrap water and fat upon heating. The use of vacuum during tumbling also reduces the incorporation of air into the extracted myofibrillar proteins. If air becomes trapped in this exudate, the bind will be weaker, reducing consumer appeal (NLSMB, 1985).

Meat tumbled in a nitrogen back-flush atmosphere had higher protein extraction values than meat treated in either vacuum or nonvacuum. However, each of the atmosphere conditions produced restructured, cured beef that was acceptable, and non-vacuum tumbling produced a product with higher yields (Ghavimi et al., 1986). Meat tumbled at 15 and 20 rpm had higher instron peak values than the meat tumbled at 5 or 10 rpm. However, 20 rpm produced more extracted protein on the meat surface than 5 rpm. The 15 rpm tumbling speed caused greater binding ability (Ghavimi et al., 1987).

Stirring during massaging results in compression and the application of frictional energy uniformly to all the meat pieces within the vat. Most product is left in the massager for at least four hr, and many products are

massaged for 16 to 18 hr, often with alternating rest and stirring periods of about 15 to 20 min. each. As action time increased or rest period declined in the massaging cycles, the bind increased in a linear and quadratic manner (Siegel et al., 1978; Gillett et al., 1982). Continuous massaging appears to be a better practice than intermittent massaging. When massagers are used in a restructured meat system, care should be exercised to assure close temperature control (NLSMB, 1985). The effect of high environment massaging temperature (10 ^{O}C) can be considered detrimental to bind. However, since high temperature also reduces voids and enhances cure color intensity, relatively high temperature massaging (7°C) is still recommended (Gillett et al., 1982).

Salt/Phosphate Levels

The addition of NaCl to meat masses intended for use in restructured meat products is widely practiced as a means of enhancing and expediting the extraction of myosin. The yield of salt-soluble proteins extractable from muscle decreased over the immediate post-slaughter period (Solomon et al., 1980). The postmortem enzyme hydrolysis of ATP caused a decrease in the solubility of myofibrillar proteins whether or not sodium chloride was present, and grinding of muscle prerigor caused glycolysis to be accelerated. Therefore, particularly when ground, prerigor meat is to be incorporated into a restructured meat

product, salt should be incorporated into the prerigor meat as early as practicable in order to achieve greatest myofibrillar solubilization (Hamm, 1977). Extraction of the proteins from meat increased directly with the salt concentration in the aqueous extraction medium up to about 10 % salt (Gillett et al., 1977).

Generally, salt is expected to have an adverse effect on meat color, but there is some evidences that salt and/or tripolyphosphates added to meat may have had a beneficial effect on color (Huffman et al., 1981). Salt addition to beef has been shown to increase rancidity after 90 days of freezer storage (Booren et al., 1981c).

Cooking yields in patties have been shown to be increased by the addition of both salt and tripolyphosphate (Huffman et al., 1981). The addition of salt at either 2 or 3 % with tripolyphosphate increased cooking yield in beef rolls (Moore et al., 1976). At 1 % salt and 0.25 % tripolyphosphate in beef rolls, however, no effect was shown on cooking yield (Pepper et al., 1975).

Flavor of patties has been scored higher for those containing both salt and polyphosphate than for salt alone and salt alone was superior to either tripolyphosphate alone or the controls containing no additives (Huffman et al., 1981).

Adhesion scores for patties were highest for salt alone or salt plus tripolyphosphate, but tripolyphosphate

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alone was superior to the controls containing no additives (Huffman et al., 1981). The binding ability of myosin increased linearly with increased levels of both salt and phosphate (Moore et al., 1976; Pepper et al., 1975). Instron measurements of binding strength in cooked beef rolls were increased by salt plus tripolyphosphate over those containing salt alone (Huffman et al., 1981). Cooked beef rolls were more tender (lower Kramer shear force value) containing 1.5 % salt than in those in which no salt was added (Furumoto et al., 1980).

Most studies of polyphosphates in meat products have focused on their influence on water holding capacity. The following mechanisms have been proposed to account for their action (Trout and Schmidt, 1983): (1) increase in pH; (2) increase in ionic strength; (3) chelation of divalent metal ions; (4) direct binding to meat proteins, and (5) dissociation of actomyosin. Of these mechanisms, an increase in ionic strength and pH are the most important in relation to water-binding capacity and binding in beef rolls (Trout and Schmidt 1983,1984).

At pH 5.5, maximum swelling of myofibrils occurs in 0.8 M NaCl when no sodium pyrophosphate is present and in 0.4 M NaCl when 10 mM pyrophosphate is present. Because the swelling of myofibrils is very small in 0.4 M NaCl without pyrophosphate, pyrophosphate appears to exert a synergistic effect (Offer and Trinick, 1983). In the

absence of pyrophosphate, extraction of myosin begins at the center of the A-band, but in its presence extraction begins at both ends of the A-band. Addition of pyrophosphate to buffer solutions results in myosin being extracted much more effectively.

Restructured beef steaks formulated with 0.5 % sodium tripolyphosphate (STP) or sodium hexametaphosphate (SHMP) had more desirable raw color scores than the control or steaks made with sodium acid pyrophosphate (SAPP) (Miller et al., 1986c). Addition of 0.25 % or 0.5 % polyphosphate to restructured, battered and breaded, cooked, nugget products protected them from off-flavors and lipid oxidation (Huffman et al., 1987).

Since the recent dietary concerns about excess sodium intake, there is increased interest in reducing NaCl levels in further processed products. Salt level could be reduced from 3.0 to 1.5 % in preblends without any storage problem if phosphate (0.5 %) was included (Choi et al., 1987). The addition of 0.2 % phosphate to restructured beef steaks containing 0.2 % salt enhanced texture with no detrimental effects on color (Lamkey et al., 1986). The most desirable of 20 combinations of salt (0, 0.75, 1.5, and 2.25 %) and phosphate (0, 0.125, 0.25, 0.375, and 0.5 %) was 0.75 % salt and 0.125 % phosphate in restructured pork (Schwartz and Mandigo).

Addition of NaCl, KCl, $CaCl_2$, or $MgCl_2$ to restructured

steaks resulted in reduced storage times and increased lipid oxidation. Restructured steaks made with 0.5 or 1.0 % KCl, 0.5 % $MgCl_2$ and 0.5 % $CaCl_2$ were more desirable and darker red in raw color than blends formulated with 0.5 or 1.0 % NaCl. However, $MgCl_2$ and $CaCl_2$ salts added at the 1.0 % level caused an undesirable off-flavor in restructured steaks and resulted in lower sensory ratings (Miller et al., 1986b). Partial replacement of NaCl ionic strength with 50 % or less of KCl in tumbled ham can be accomplished while maintaining acceptable sensory and physical attributes (Frye et al., 1986).

Temperature and pH

Rapid decreases in postmortem pH or slow postmortem chilling of muscle can result in warm muscle at a low pH. Such conditions can result in decreased extractability of the myofibrillar and sarcoplasmic proteins from postrigor muscle. The condition is well known in pig carcasses, and the affected muscles are referred to as PSE (pale, soft, and exudative) (Sayre and Briskey, 1963).

Protein extractability from postrigor meat is largely depend on the ultimate pH of the meat. The higher the pH, the more extractable the proteins (Davey and Gilbert, 1968). Substantial degradation of myosin heavy chain occurs when muscle is stored at relatively high temperatures (37 ^{O}C) (Yates et al., 1983). Decreased protein extractability was reported in beef muscle stored at -4 ^{O}C (Awad et al.,

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1968), in beef and pork muscles stored at -17.8 °C (Miller et al., 1980). Grinding and flaking at temperatures of 32 °, 2 ° and -5 °C have been studied. As temperature decreased, cooking yield decreased with lower water holding capacity and lower percent protein extracted from the colder meat blocks (Chesney et al., 1978). The highest quality restructured pork product was produced when a mixture of 2 ° and -5 °C product were used in a 50 : 50 blend (Popenhagen and Mandigo, 1978). Binding strength decreased with decreased temperature of the meat mix when formed into patties over the temperature range -1 ° to -5 °C (Macfarlane et al., 1986).

The binding between meat pieces is a heat-initiated reaction, since no binding occurs in the raw state. Heating caused the previously dissolved proteins to rearrange so that they could interact with the insoluble proteins on the meat surface, and in so doing formed a cohesive structure (Kotter and Fisher, 1975). Binding strength of crude beef myosin started to increase at 55 °C, then increased linearly with temperature to 80 °C (Siegel and Schmidt, 1979). Binding strength is a function of the interaction between the temperature of heating and the presence and concentration of different salts. The exact interaction has not been clearly elucidated, but the temperature at which maximum binding occurs is dependent on the presence of specific salts and hence the ionic strength and pH

(Quinn et al., 1980). Pre-cooked, reheated steaks had a significantly higher binding strength, but a lower cook yield than those steaks cooked from the frozen, raw state (Wiebe and Schmidt, 1982).

Pressure

Pre-rigor pressurized (15,000 psi) beef used in the manufacture of restructured steaks, resulted in acceptable textural properties appear obtainable without the use of NaCl (Berry et al., 1986). Application of high pressure (145,000 - 220,000 psi) to patties prepared from comminuted meat has been shown to increase the cohesion between meat particles in the cooked patty (Macfarlane et al., 1984).

Increased pressure would be expected to favor the disruption of ionic bonds and hydrophobic interactions between protein molecules, and the stabilization of hydrogen bonds. Because ionic bonding is important in the stabilization of the myofibrillar proteins in muscle , application of pressure would be expected to promote the stabilization of these proteins in saline solution (Macfarlane and McKenzie, 1976). No significant effects of pressure of 200, 600 or 1,000 psi were observed on any cooking characteristics or sensory attribute studied including cooking time; cooking loss of moisture, fat or total losses; cooked composition; sensory evaluation of degree of doneness; flavor; juiciness; texture desirability or description; tenderness or overall palatability

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(Costello et al., 1981), but increased pressure (200-2,000 psi) applied to form the restructured patty with no added salt can increase binding strength (Macfarlane et al., 1986).

Protein Additives

Meat Origin

Myosin has been shown to be superior as a binding agent compared to actomyosin at low (0.2 M) and moderate (0.8 M) sodium chloride concentrations but was not different at high (>1.0 M) salt concentrations. The presence of sarcoplasmic protein with myosin enhanced binding strength at low ionic strength but decreased the bind at higher salt concentrations (Macfarlane et al., 1977). Ford et al., 1978 evaluated chunked and formed beef steaks containing added myosin and/or sarcoplasmic protein with various salt levels by physical, sensory and instrumental texture evaluation methods. They concluded that myosin or a mixture of myosin with sarcoplasmic protein, with little or no added salt, had potential for binding together pieces of meat to produce a cohesive restructured meat product of low salt content (<0.4 M).

Gelatin is a derivative of collagen. The overabundance of stromal proteins (connective tissue) results in very poor bind while the lack of stromal proteins yielded products that were soft, jelly like and lacked cohesion.

During conversion of collagen to gelatin, intermolecular forces are disrupted, peptide bonds are hydrolyzed, and crosslinking bonds are broken (Paul, 1972). Froning (1966) found gelatin added to chicken loaves increased the bind of products. Gelatin may prove useful as a raw binder.

Surimi

Surimi is a Japanese term for mechanically deboned fish flesh that has been washed with water and mixed with cryoprotectants to enhance frozen storage (Lee, 1984). A white, odorless, tasteless fish protein with superior gelling ability, surimi is used as an intermediate value product in a variety of restructured seafood analogues, such as fabricated crab legs, crab flakes, shrimp, scallops, fish sticks and fish sausage products such as Kamamoko (Andres, 1984; Mitchell, 1984).

In the surimi process, fish are headed, gutted and cleaned in a wash tank. Backbones are removed and the washed fish are put through a belt-drum-type meat separator, which separate the flesh from the bones and skin. Basically, surimi is produced by repeatedly washing the mechanically separated fish flesh with chilled water (5° - $10\ ^OC$) until it becomes odorless and tasteless. Washing removes fat and undesirable materials such as blood, pigments, enzymes, odorous substances and other water-soluble components that could decrease the shelf life and palatability of the product. Washing also increases the

level of actomyosin, the myofibrillar salt-soluble protein responsible for the gel strength and elasticity of surimi. Washing is followed by dewatering to a level of 75 - 78 % moisture with the aid of a screw dehydrator. The resulting material is pressed through a strainer to remove small particles, such as bones, skin and scales. The washed flesh is then mixed in a silent cutter or a ribbon blender with cryoprotectants (4 % sugar, 4% sorbitol and 0.2 % polyphosphates), extruded into plastic bags and frozen. The cryoprotectants prevent denaturation of muscle proteins, especially actomyosin, during frozen storage. Frozen surimi has a shelf life of 1 yr when stored at a constant temperature below -20 ^oC. However, if surimi is stored at -10 ^oC, its gel formation ability decreases and the product becomes useless after 3 mo (Lanier, 1984; Lee, 1984).

The bland flavor and excellent binding properties of surimi suggested that it could be used as a supplemental ingredient in processed meat. It is too early, however, to predict the impact of surimi on the meat industry. A major handicap is the relatively poor yield (22 - 32 %) from processing whole fish to surimi (Kotula et al., 1987).

Nonmeat Origin

A wide variety of nonmeat protein products can be added during processing to improve water or fat binding, cooking yield, slicing characteristics and flavor, as well as reducing formulation costs. The functionality of such

extenders or binders varies with the source, the protein concentration, and, in some cases, the manner in which the proteins structure or solubility has been altered during manufacture. The most commonly used extenders are derived from milk or soybeans.

Nonmeat proteins ranked in descending order of binding ability were wheat gluten, egg white, corn gluten, calcium reduced dried skim milk, bovine blood plasma, isolated soy protein and sodium caseinate. Only wheat gluten, bovine blood plasma and soy protein isolate were able to bind in the absence of added salt (Siegel et al., 1979). Modified whey solids at the 2% level had the highest binding strength of the nonmeat proteins (soy isolate, textured soy protein and modified whey solids at the 1, 2 or 3 % levels) that were evaluated (Moore et al., 1976).

Hand et al., 1981 compared meat, meat + vital wheat gluten (VWG) and meat + isolated soy protein (ISP) each with or without flavoring (0.44% NaCl, 0.25% sodium triphosphate and 0.31% hydrolysed vegetable protein). Off flavors were judged significantly greater for the meat plus isolated soy protein in the absence of flavoring. All products made with flavoring were more juicy, less easily fragmented and more cohesive than those without flavorings. The addition of flavoring improved the cooking yield when added to the meat plus isolated soy protein. Cooking yield was significantly higher for the meat + ISP + flavorings

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than any combination studied except meat plus flavorings. But Miller et al., 1986a reported meat + MSB (mechanically separated beef) steaks sustained lower cooking losses than VWG or soy protein extended steaks.

Plant proteins may detrimentally affected color and influence consumer selection. Metal ions and/or insoluble materials in the plant proteins may interfere with hydration mechanisms of these protein products, as well as hydration of myofibrillar proteins at the meat surfaces, and thus decrease binding (Terrell et al., 1982). The use of high levels of plant proteins may cause problems in emulsion stability, texture, flavor and color (Mittal and Usborne, 1985). Corn germ protein increased water holding capacity and the thermal stability of comminuted meat products at levels of 2 - 4 % (Lin and Zayas, 1987).

Nonprotein Additives

Water

The amount of water that can be legally added to restructured meat products depends on both type and quality of the product. Generally speaking, the amount varies from none for many flaked or chunked restructured steaks and rolls, to as high as 30% for certain sectioned and formed products. With flaked and chunked products, the water is normally added directly to the product during mixing, whereas with sectioned and formed products, it is added to

the product by needle injection prior to mechanical treatment (Trout and Schmidt, 1987).

In the manufacture of restructured steaks and rolls, water is added mainly to dissolve the salt and phosphate so that they can be evenly distributed throughout the product. If products are precooked, water also helps compensate for evaporation losses. Too much added water reduces the functional properties of a product by decreasing the concentration of the meat proteins and endogenous salts. If too little water is added, a product will be dry and lack flavor (Trout and Schmidt, 1987).

Difficulties may be encountered when water added to the product is " hard ", because the higher content of calcium interferes with extraction of salt soluble protein so functional characteristics are reduced. High concentration of nitrate or nitrite may result in a persistent red color in the product. Very high levels of metal ions, such as iron, may catalyze rancidity in the products to which such water is added (Kropf, 1988).

Nitrite

Nitrite was historically associated with the addition of salt to preserve meat. However, curing now is understood to refer to the use of salt in combination with sodium or potassium nitrite and other ingredients for preserving and flavoring meat. Nitrite is the critical agent in meat curing because it imparts a preservative effect, is an

effective antioxidant, stabilizes color and also contributes to and stabilizes flavor. In the case of refrigerated or frozen restructured products, nitrite enhances shelf life and inhibits oxidative rancidity (NLSMB, 1985).

Of the nitrite added to meat for the purpose of curing, less than 50% can be accounted for in the finished product (Cassens et al., 1974). USDA regulation levels of in-going nitrite level of ham and bacon are not over 156 and 120 ppm respectively. Factors that affect the level of detectable residual nitrite are: (1) time and temperature employed during processing; (2) amount of protein; (3) concentration of salt; (4) concentration of nitrite; (5) numbers and kind of microorganisms; (6) acidity; (7) amount of nitrite added; (8) length of storage; (9) oxygen exposure (NLSMB, 1985).

When nitrite is first added to the meat, the myoglobin color changes from purple or red to brown. With time and reducing conditions, the color changes to the dark red of nitric oxide myoglobin. Heat denaturation fixes the pigment as stable nitrosylhemochrome, which is pink (NLSMB, 1985).

Another major function of nitrite is its role in delaying Clostridium botulinum growth and toxin production when cured meats are abused at elevated temperature. Both NaCl and nitrite become increasingly inhibitory as pH is reduced from 7.0 to 6.0. A water activity of less than 0.93

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is also an adequate inhibitor of all types of this organism. Continuous storage of products at 3.3 °C or colder is an adequate control for its growth and toxin production. Heat treatments to kill the spores are quite drastic and radiation sterilization inactivates it (Kropf, 1988).

Cure Accelerators

Cure accelerators are compounds that enhance the rate of color development in nitrite treated meat products. The acid and sodium salt forms of ascorbate, erythorbate, and citrate are commonly used. Acidifiers such as glucono-delta-lactone and sodium acid pyrophosphate also accelerate color fixation. USDA regulations of the quantities used are 0.05% erythorbate or ascorbate, and 0.5% glucono-delta-lactone or sodium acid pyrophosphate. Citrate is used as a spray on cured cuts prior to packaging (Trout and Schmidt, 1987).

Sweeteners

Only four sweeteners (sucrose, dextrose, lactose, and corn syrup or corn syrup solids) are widely used. The use of sucrose and dextrose is not limited because their sweetness itself is self-limiting. Dextrose is one- half to two-thirds as sweet as sucrose and is used at about the 1.0% level. Corn syrup and corn syrup solids may be classified according to their dextrose equivalent (DE), which is a measure of the reducing-sugar content calculated

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as dextrose and expressed as a percentage of the total dry substance. USDA regulations limit the amount of corn syrup permitted in sausage to 2.2 % and of corn syrup solids to 2.0 %, with no limitations on their use in non-specific loaves (Trout and Schmidt, 1987).

Flavorings

Flavorings used in preparation of restructured meat products may be mixtures of various spices or may be other substances such as monosodium glutamate, hydrolyzed plant proteins and flavor nucleotides. Certain spices such as black pepper, cloves, ginger, mace and thyme also possess antioxidant properties (Trout and Schmidt, 1987).

Spices are dried vegetable substances. Spices are used either whole or as ground spices, essential oils or oleo-resins. Ground spices are more easily dispersed throughout a product than are whole spices. Essential oils are volatile oils that are removed from plants by either steam distillation, absorption on neutral fat, or enzymatic action followed by steam distillation. Oleo-resins are viscous, resinous materials obtained by extracting ground spices with volatile solvents. The solvents are than removed to leave the flavor and aromatic compounds. The use of spice extractives helps to eliminate color specks, bacteria, excessive shipping costs and large storage areas associated with the use of whole spices (Trout and Schmidt,

1987).

Hydrolyzed vegetable proteins (HVP) are blends of corn, wheat, soy and other proteins that have been hydrolysed to yield a series of meat-like flavorings. They are designed to supplement extracts of meat, and while most widely used with beef, are also available in pork flavors for use in a variety of foods. HVP are available as granules, powders and bouillon seasoning granules. Other components, such as smoke flavoring, caramel color, monosodium glutamate, disodium inosinate and disodium quanylate may be added to the HVP (Trout and Schmidt, 1987).

Smoke

Historically smoke has been used to preserve, flavor and color meat products. Liquid smoke can be used as a replacement for the natural smoking process. Liquid smoke is produced from the fraction of smoke with polycyclic hydrocarbons removed by filtration. Liquid smoke is principally applied by drenching, atomizing or direct addition. During drenching the meat product is either sprayed, showered or dipped in a solution of liquid smoke and water. Atomizing disperses fine droplets of liquid smoke into a smokehouse where these droplets are deposited on the product. It may also be added directly to the meat mix, but must be pH buffered if used in this way, because the acid pH of liquid smoke will cause a breakdown of the

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product structure. Only approved smoke flavorings may be utilized and must be listed on the label (Trout and Schmidt, 1987).

Chemical components of smoke can be grouped into four major classes: (1) acid components; (2) phenolic compounds; (3) carbonyl compounds and (4) hydrocarbons. The acidic compounds accelerate the nitrite reaction and contribute to surface skin formation. The reaction of carbonyl and the amino group of meat proteins forms the smoky brown color. The hydrocarbons, especially polycyclic compounds such as benzopyrene are undesirable because they are carcinogens (Schneck, 1981).

Humidity interacts with meat products to influence absorption of phenols (Daun, 1979). Humidity has a marked influence on phenol absorption into lean at temperatures below 71 ^{o}C, with a two-fold increase in absorption between 40 and 80 % RH. This effect is not observed at temperatures above 71 ^{o}C.

Polysaccharide Hydrocolloids

Hydrocolloids, commonly referred to as gums, are hydrophilic substances that form viscous solutions or dispersions when mixed with water. Most gums are complex polysaccharides, which may be derived from starches and celluloses, may occur naturally as seed gums, plant exudate gums, seaweed gums, and microbial gums or be obtained by complete chemical synthesis (Igoe, 1982). Gelation of

hydrocolloids could prove very useful in fresh restructured meat products such as restructured steaks and roasts.

Guar gum has been reported as being a very efficient " water binder " in comminuted meat products, canned meats and pet foods (Sanderson, 1981). The anionic gums, carrageenan and xanthan gum, stabilized the texture of frankfurter emulsions against acid deterioration at 37 °C in vinegar pickle (Fox et al., 1983).

Kappa-carrageenan and iota-carrageenan form higher-viscosity solutions or stronger gels upon addition of potassium or calcium cations, respectively (Sanderson, 1981; Igoe, 1982). Dilute solutions of guar gum and locust bean gum increase in viscosity upon addition of simple sugars (Elfak et al., 1977). Kappa and iota carrageenan may find application in sodium-reduced and/or low-fat comminuted meat systems, in which functionality of the traditional myosin heat-set matrix is limited due to low ionic strength (Foegeding and Ramsey, 1986). Gums selectively affect various textural and stability properties and could be used in combination to achieve specific textural and stability goals (Foegeding and Ramsey, 1987).

Alginates

While the traditional myosin heat-set gelation mechanism can adequately bind restructured meat products in the cooked state, this system does not bind uncooked meat

pieces. An algin/calcium gelation mechanism can be successfully used to produce restructured beef products which possess acceptable binding characteristics in both the raw and cooked state (Means and Schmidt, 1986).

When a dry mixture of sodium alginate (0.7 - 1.0 %), calcium carbonate (0.10 - 0.25 %) and glucono-delta-lactone (GDL 0.20 - 0.30 %) is added to raw meat, these materials react to form calcium alginate, a gel that holds the pieces together whether refrigerated, frozen or cooked. Sodium alginate, the water soluble salt of alginic acid, reacts with the Ca^{2+} ions released upon slow hydrolysis of $CaCO_3$. A strong Ca-alginate gel is formed, which serves to bind the meat pieces together. GDL serves to modify pH and upon slow hydrolysis releases hydrogen ions. This stimulates faster release of Ca^{2+} ions from $CaCO_3$, but allows adequate time for product manufacture and forming. GDL also improves the flavor of the cooked product by lowering the pH of the meat. Use of other food grade acidulants (lactic acid and calcium lactate) may also be appropriate. The final product is allowed to contain up to 1.0 % sodium alginate, 0.2 % calcium carbonate and 0.3 % each of lactic acid and calcium lactate. The binder material must be declared as part of the product name.

Production of restructured meat products using the algin/calcium method does not require addition of NaCl or phosphates for effective binding. Thus, the detrimental

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effects of NaCl on oxidative rancidity development and discoloration of refrigerated and frozen restructured products can be avoided. Algin/calcium structured beef steaks exhibited better binding and color in the raw state, but had lower palatability scores in the cooked state than salt and phosphate restructured products. More research is needed to explain the more rapid microbial growth and quality deterioration of algin/calcium products stored in vacuum packages (Means et al., 1987).

Antioxidants

Phospholipids are probably the major lipids involved in the development of "warmed-over-flavor" (WOF, Pearson et al., 1983). Procedures for preventing development of WOF include (1) the production of antioxidative materials by overheating or retorting of meat; (2) the addition of nitrite; (3) the use of phosphates or other chelating agents; (4) the addition of synthetic antioxidants; (5) the addition of high levels of ascorbates and (6) use of substances possessing natural antioxidant activity (Pearson et al., 1977).

Butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) are extremely soluble in fat and insoluble in water and have good carry through effect. Tertiary butylhydroquinone (TBHQ) has excellent carry through and is adequately soluble in fat. Because it chelates iron to form an unsightly blue-black complex,

propyl gallate (PG) is always used in combination with the chelator citric acid. PG has good synergism with BHA and BHT, but is prohibited from use with TBHQ.

BHA provided the best protection of color, while TBHQ had a slightly greater protective effect against rancidity (Chastain et al., 1982). Sodium tripolyphosphate (STPP) helped to inhibit formation of off-flavors and decreased TBA values in flaked and formed beef steaks and in chunked and formed beef roasts (Smith, 1983).

Shahidi et al., 1987 reported BHA, BHT, PG, TBHQ, trihydroxybutyrophenone (THBP), nordihydroguaiaretic acid (NDGA), catechol and ethoxyquin were effective antioxidants at a level of 200 ppm. BHA, TBHQ and ethoxyquin were equally effective at a level of 30 ppm. Ascorbyl palmitate effectively retarded lipid oxidation. The cooked cured-meat pigment, dinitrosyl ferrohemochrome, showed some antioxidant effect which increased with increasing concentration, and at 18-24 ppm was as effective as 200 ppm of alpha-tocopherol.

Antimicrobials

The effectiveness of an antimicrobial is influenced by characteristics of the food, especially its water activity and initial contamination level. Other added ingredients such as salts, sugars, spices and smoke also have an influence. A list of antimicrobials that may be added to or are natural constituents of restructured products includes

organic acids and their salts, parabens, sulfites, nitrites, epoxides and diethyl pyrocarbonate (Kropf, 1988).

The organic acids include acetic, benzoic, propionic and sorbic and their derivatives. Acetic acid (vinegar) and the sodium and calcium acetates and diacetate are generally recognized as safe (GRAS) and assert their antimicrobial activity up to pH 4.5. Their primary targets are yeasts and bacteria as they are less effective against molds. Sodium benzoate is GRAS but its application in muscle foods is limited to a dipping solution. Sodium and calcium propionate are not used in muscle foods. Sorbic acid is more effective against yeasts and molds than against bacteria. Use of 0.26 % potassium sorbate allows reduction of nitrite levels from 120 to 40 ppm, while still maintaining effectiveness against Clostridium botulinum (Kropf, 1988).

Parabens is the name given to the alkyl esters of parahydroxy benzoic acid. They are the only phenols currently approved for microbial preservation of foods and are particularly effective against molds and yeasts and less effective against bacteria, especially gram negative ones. Only methyl and propyl parabens are GRAS and combined use is limited to 0.1 % (Kropf, 1988).

Several gram-negative and gram-positive bacteria are inhibited by phenolic antioxidants; gram-positive are generally more sensitive. Usually 150 ppm or more were

necessary to inhibit some pathogenic organisms and 100 ppm inhibited formation of S. aureus enterotoxin.

Sulfiting agents can destroy thiamine and its use is not allowed in foods which contribute more than 10 % of the thiamine recommended dietary allowance. Sulfite also restores red color to meat, giving it a false appearance of freshness (Kropf, 1988).

Temperature Reduction

Many restructured meat product operations start with frozen raw material. Subsequently it is thawed, processed, cooked and frozen before shipping. Freezing temperatures are critical when producing restructured meat products. Protein solubilization is optimized at 0 $^{\circ}$ to -5 $^{\circ}$C. Myoglobin undergoes severe oxidation at -5 $^{\circ}$ to -15 $^{\circ}$C (Brown and Dolev, 1963) with the greatest amount of oxidation at -11 $^{\circ}$C (Zachariah and Satterlee, 1973). Thus frozen storage below -17 $^{\circ}$C was recommended.

It is advantageous to use fresh meat whenever possible. When frozen meat must be used, tempering to -2 $^{\circ}$ to -4 $^{\circ}$C in a cold room or by microwave tempering before comminution is wise. Meat thawed in cool or warm water will suffer considerable leaching of protein, degradation of color and loss of protein functionality (NLSMB, 1985).

If merchandized frozen, finished products should be rapidly frozen (-18 $^{\circ}$C or below) and maintained at that

temperature throughout storage and distribution. Extending the shelf life of cooked and frozen products includes preventing rancid or warmed-over flavors. A rapid transfer from cooking to an efficient cooling and freezing system will aid in minimizing this kind of product deterioration, and should be followed by packaging under vacuum or inert gas-flushing (NLSMB, 1985).

Microwave Tempering

When a freeze-tempering system is used during restructuring, large tempering rooms are often necessary to temper the logs prior to pressing. Tempering, which may take as long as 48 hr, can subject significant volumes of restructured products to temperatures that can be detrimental to color and oxidative stability (Zachariah and Satterlee, 1973). Microwave tempering helps to eliminate this problem by speeding up the process.

Depending upon the product, microwave units can temper frozen logs to -8 $^{\circ}$ to -2 $^{\circ}$C. A tempering room is still needed because thermal equilibration of the logs is necessary prior to pressing. Microwave tempering usually results in uniform temperature distribution throughout the logs (Decareau, 1984).

Forming Methods

Restructured products must be formed into the desired size and shape. Four basic types of processes include: (1) product is stuffed into a casing, then frozen and tempered, then pressed and sliced or diced; (2) product may be placed in a forming container in which it is cooked and chilled prior to slicing or dicing; (3) product may be formed into a patty or other shape using a slide plate forming machine such as has been traditionally used for forming hamburger patties; (4) product may be formed on a cavity fill forming machine (NLSMB, 1985).

Machines for shaping hamburger patties have been modified to produce restructured steaks, chops and other restructured products. Forming machines of this type have the advantage of being continuous and rapid. Care must be taken to prevent defects in shape and/or bind during product transfer before freezing or cooking. Patty formers also limit the size of the pieces to be restructured. Generally they are used to produce acceptable flaked or chunked restructured products (Booren and Mandigo, 1987). The shaped meat is dropped on to a belt that trasfers it to a freezer tunnel, a battering and breading machine or a continuous cooker.

Various methods of forming meat balls and cubes for such items as sweet and sour pork are available. Perhaps the most common of these is the cavity fill machine. If

this equipment is properly integrated into the processing line, the meat items can be filled into cans for heat processing or breaded, battered and fully cooked. The cavity fill machine can be used for shaping nearly any item desired (NLSMB, 1985).

Pressing

Hydraulic presses are used to shape tempered logs prior to portioning. They consist of a two-dimensional mold and a hydraulic ram that forces the tempered muscle to flow into the specific shape of the mold. Pressures of 100-1,000 psi are used for a short duration. The purpose of pressing is to shape and force meat pieces into close contact with each other.

Presses by their nature are batch processes and can constitute a limiting factor in the production scheme. Scheduling of specific shapes or forms of dies for log pressing is important because the time required to dismantle and reassemble a press to change die shapes is considerable (Booren and Mandigo, 1987).

Cleaving

After restructured meats have undergone a stuff-freeze-temper-press sequence, the next step is portioning. This operation is most often accomplished by slicing with one of several different types of machines. Deli- type slicers with spinning circular blades can be used to

produce both thick or thin slices. Deli slicers are designed for cooked material, and they usually must be modified for slicing tempered logs.

Power cleavers are the most widely used type of equipment for portioning steaks or chops from tempered logs (-5 ° to -2 °C). Portioning is achieved by controlling thickness; since the logs are pressed to a uniform size, portion weights are quite accurate. The portion cleaved from each end of a log is frequently a "miscut". This disadvantage can be minimized by "facing" one end on a saw or slicer; however, facing is a time-consuming, labor-intensive batch process and is usually avoided. Miscuts during slicing can be as low as 2 - 3 % or as high as 15 % depending upon a variety of factors (e.g., stuffing technique, tempering temperature, pressing technique, blade design and maintenance) (Booren and Mandigo, 1987).

Cooking Systems

A major problem with fresh, frozen restructured products is the loss of control from a finished frozen product until cooking is completed by the consumer. Handling conditions and treatment prior to heating will affect bind, as well as color and flavor. One method of developing bind and controlling conditions prior to heat-initiated binding in

fresh, frozen restructured products is to cook these

products during the production process. Precooked rolls or roasts for delicatessen operations and breaded, cooked restructured steaks, chops or nuggets, which are then frozen, are examples of this approach (NLSMB).

Cook-in Systems

This relatively new approach involves lining molds with special roll stock film, then filling the molds with meat chunks. A second type of roll stock film is sealed under vacuum onto the top of the container. The closed two part pouch is placed into molds of the desired shape, which are spring-pressured, cooked in a smoke house and chilled. The cooked product assumes the shape of the mold, and, because it is not touched after it has been cooked, it has a very low bacterial count. Thus, under proper refrigeration it has an extended shelf life (NLSMB, 1985).

Convection Oven

Products requiring roasting, baking or drying often are cooked in convection ovens. Uniform degree of doneness and desired levels of weight loss demand close control of airflow, air velocity, uniformity of temperature and relative humidity. Economy of operation demands close monitoring of heat loss. Purchasing decisions on this kind of equipment require matching cooker size to batch size, choosing a continuous oven for product made daily in large amounts or a smaller modular cooker for efficient use in different kinds of lower-volume products (NLSMB, 1985).

Deep-Fat Fryer

These are widely used to cook breaded and battered items, such as nuggets, patties, sticks and similar shapes. Fresh and pure cooking oil is essential for product flavor stability. Maximum heat retention and energy efficiency is important in design of this type of equipment. There should be provisions for filtering the fat and for maintaining fat level. It may be desirable to prefry some products to give them a crispy texture on the outside, and then finish cooking in some other system, such as a counterflow oven (NLSMB, 1985).

Broiler

Broiling give a brown surface to restructured meat products. It can be done with various conveyer belt designs to impart a grilled-appearing pattern to both sides of the product, which may be flame-broiled to a specific degree of doneness or merely seared for final cooking in an alternative cooking system. Maximum energy efficiency is important in system design, and such features as automatic shutdown and control of dripping recovery are necessary for fire prevention (NLSMB, 1985).

High-Humidity Cooker

This type of continuous cooking system is extremely efficient for further cooking individual portions such as meat balls, patties and chops and also offers minimum product weight loss. High humidity in a convection system

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helps to maintain precise temperature control. This system works well in combination with other systems to finish the cooking of seared or prefried products, which can be conveyed directly into a continuous freezing system after cooking (NLSMB, 1985).

Water-Immersion Cooker

Product packed in a heat-stable and moisture impermeable container is passed through a shower of heated water in a cabinet, suspended on a rack in a recirculating water shower, or suspended on a rack immersed in a circulating water bath. Uniformity of water temperature and control of heat loss to the environment are essential, and there should be a system for monitoring product temperature to assure uniform heating of all product throughout the system. If the temperature of the cooking water is maintained at no more than 2 ^{o} to 6 ^{o}C higher than the desired final product temperature, both overcooking of outer layers of the product and excessive cooking loss will be prevented. Such a system is very adaptable to cooking injected beef/pork roast as well as restructured beef/pork rolls and corned beef loaves (NLSMB, 1985).

Retort

Retorting for processing metal containers and film pouches to a state of commercial sterility has been in use for many years. The degree of heating for shelf stability is likely to cause texture and flavor deterioration in most

meat products, but the use of containers that are small in at least one dimension can reduce cooking times, thus helping to protect product quality. Energy efficiency and monitoring ability as well as safety are important purchasing considerations. Records must be maintained on each batch and every container must be adequately heated are vital to microbiological safety (NLSMB, 1985).

Packaging

A major trend in the packaging of meat products, especially those that are restructured, is to provide added value through cook-in-the-bag systems or meal-ready approaches. The use of packages that provide product protection as well as enhanced convenience is critical to the successful marketing of these products. Four major problems related to the packaging of restructured meat products are microbial spoilage, change in color, lipid oxidation and moisture loss. Since most restructured meat products are distributed frozen, microbial spoilage is generally limited to cured, packaged meats. The amount and extent of microbial spoilage is affected by species type, product type, product surface area, type of packaging and storage conditions, including temperature and relative humidity (Harte, 1987).

Headspace Control Technique - Vacuum and Gas-Flush Packaging

Vacuum and gas-flush packaging are used to (1) control oxidation; (2) control microbial growth; (3) fix or maintain the desirable color of perishable food products such as meats; (4) increase water retention and (5) reduce freezer burn (Harte, 1987).

Vacuum packaging is usually described as packaging in containers, whether rigid or flexible, from which substantially all air has been removed prior to final sealing of the container. The degree of evacuation required in a vacuum package and the level of oxygen barrier required are directly related to the susceptibility of the contents to deterioration by oxygen and to the shelf life required for that product (Harte, 1987).

Gas-flush packaging, often called controlled-atmosphere packaging or modified-atmosphere packaging, is essentially a technique whereby gas is introduced into a container system of controlled barrier properties. Gas flushing generally is done with nitrogen or carbon dioxide. Nitrogen usually is less expensive, but it does not possess the same antimycotic effect that carbon dioxide does. Nitrogen functions as an inert gas to reduce the concentration of oxygen in the package headspace (Harte, 1987).

Certain problems may be associated with the use of gas-flush or vacuum packaging. For example, product with sharp corners may puncture a vacuum package, allowing gases

to enter and destroying the package's effectiveness. With soft products, vacuum packaging sometimes causes unacceptable compaction. Increased storage space requirements can be a problem with gas-flush flexible package. Gas flushing also requires one more step in the process. Both of these techniques typically require the use of more expensive barrier films (Harte, 1987).

Polyethylenes

Polyethylenes (PE) are polymerized from the ethylene monomer. Low-density polyethylene (LDPE) is the largest volume plastic produced (Peters, 1985). High-density polyethylene (HDPE) is also manufactured in large quantities. Increasing density markedly increases tensile strength, barrier and stiffness properties, while impact and tear resistance decrease. HDPE also has better heat and grease resistance and is more compatible with acids, alkalies, etc., than LDPE. LDPE has greater clarity than HDPE and forms a very strong seal at much lower temperatures. Both LDPE and HDPE are relatively inexpensive in comparison to other plastics (Harte, 1987).

Linear low-density polyethylene (LLDPE) is making substantial penetration into markets formerly supplied by LDPE. While the molecular structure of LLDPE differs from LDPE, its density (0.910 - 0.925 g/cm^3) is approximately the same. Films made from LLDPE have much greater tensile strength, elongation, impact strength and puncture

resistance than other PE films. This material is being used in bags and stretch wraps and as a component of laminated structure (Harte, 1987).

Ethylene Vinyl Acetates

Polyethylene is copolymerized with 5 - 20 % vinyl acetate (VA) to form ethylene vinyl acetate (EVA) which is often used as the food contact and sealing layer in flexible and semirigid packages. VA is often added to PE to improve seal performance, especially when lower temperatures are used in the sealing process. As the percentage of VA in the copolymer increases, hot tack, impact resistance, adhesion, low-temperature toughness and crack resistance increase, while stiffness, seal temperature, chemical resistance and barrier decrease. In meat packing, EVA is used as an overwrap for fresh meat, where high permeability to oxygen is required for bloom. It is also used as the sealing layer in laminate structures, such as vacuum bags and thermoforming films, because of its outstanding sealing properties (Harte, 1987).

Ionomer

Ionomers are sodium or zinc salts of ethylene/acrylic acid copolymers, containing low levels of covalent bound ions. Incorporation of these ions decrease the lipophilic nature of the polymer. Ionomers are used extensively in laminate structures to provide adhesion to aluminum foil. Ionomers are used in meat packaging primarily as the food

contact and sealing layer in a laminated structure. The most commonly used ionomer is Surlyn, which is made by Du Pont (Harte, 1987).

Polypropylene

Polypropylene (PP) is polymerized from the propylene monomer. PP is generally a good moisture barrier which is heat resistant to high temperatures, oil and grease compatible and possesses good stiffness and clarity. The major use of PP in restructured meat packaging is as a component in multilayered structures for cook-in, steam-processed items. The water barrier property and high heat tolerance of PP make it an ideal material for this application (Harte, 1987).

Polyvinyl Chloride

Polyvinyl chloride (PVC) is obtained from polymerization of the vinyl chloride monomer. It is a transparent, amorphous polymer with low heat sensitivity and begins to decompose at about 80 °C, with subsequent discoloration and liberation of hydrogen chloride. Large amounts of PVC stretch and shrink films are used for in-store packaging of fresh meats, deli meats and various cured meat products where only limited shelf life is required. These films have very high permeability to oxygen and moderately high permeability to water vapor; they also are transparent, possess good cling, are resistant to tear, have good product compatibility and are readily sealable.

Polyvinyl chloride is also used in blister and other semirigid packages for cured meat products, usually as a component in a multilayer structure (Harte, 1987).

Polystyrene

In meat packaging, polystyrene (PS) is used primarily to make thermoformed trays for all types of overwrapped meat products. PS is an amorphous, transparent plastic produced by polymerization of the styrene monomers. At room temperature PS is a hard, brittle material. Styrene can be copolymerized with butadiene to increase impact resistance. This material is commonly called high-impact PS (Harte, 1987).

Polyester

Polyester (PET) resin is produced by the condensation reaction of ethylene glycol and teraphthalic acid. This polymer is one of the most extensively used plastics in food packaging because it has superior mechanical properties, is a barrier to gases and is resistant to elevated temperatures. In meat applications, PET is commonly used as a layer in laminated structures. Because of its heat stability, strength and excellent clarity, PET is often used in vacuum packaging of meats and cook-in packaging (Harte, 1987).

Nylons

Polyamide polymers (nylons) are a family of thermoplastic materials that, when converted into films,

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possess good oxygen and aroma barrier properties and differing sensitivity to moisture. Nylons are abrasion resistant and possess excellent toughness. They are easily thermoformed and processable. Nylons are also very heat resistant, strong and resistant to most chemicals with the exception of acids. Nylons are used as a component in vacuum packaging of fresh, subprimal cuts and processed meats. Nylon materials often are used for cook-in packaging when the meat product is processed in the container (Harte, 1987).

Acrynitriles

Acrynitriles (AN) are a family of resins that, when converted into films, have good gas barrier, chemical resistance and moderately high tensile properties. The major application for AN in meat packaging is in production of thermoformed plastic containers because of its high rigidity (Harte, 1987).

Saran

Saran films are made from copolymerization of PVC and polyvinylidene chloride (PVDC). It finds tremendous usage in packaging as a coating and component in laminate structure. Saran wrap is also a very popular material used for tightly wrapping food products in institutions and homes. In meat packaging, it is used primarily as a layer in multilayer structures for pouches and bags, chubs and thermoforms, where it acts as a barrier to oxygen and water

vapor. Typical applications include boxed beef and pork, bacon, frankfurters, hams and wherever modified- or controlled- atmosphere packaging is being used (Harte, 1987).

Ethylene Vinyl Alcohol

Ethylene vinyl alcohol (EVOH) is a crystalline copolymer obtained by saponification of vinyl acetate, vinyl alcohol and ethylene. Extensive hydrogen bonding increases its crystallinity, which accounts for its high barrier characteristics. However, EVOH resins are moisture sensitive, and at higher humidity their oxygen permeability increases. To reduce moisture sensitivity, EVOH resins are usually sandwiched between polyolefins (PE, PP and PET). It is quite likely that EVOH films will find usage as a barrier material for all types of meat packages requiring an oxygen barrier (Harte, 1987).

Product Application

Restructured meats that are fabricated into luncheon meats, cold cuts and other similar products can be packaged in overwrapped trays or, more commonly, vacuumed and/or packaged in a modified atmosphere in a variety of packages including form/fill/seal pouches, blister packs, shrink packs and skin packs. Wafer-sliced ham, pastrami, etc., are often packaged in a modified atmosphere to prevent the slices from sticking together (Harte, 1987).

Products that are processed by a cook-in film

technique include hams, roast beef, corned beef, pork ribs, veal, pork roasts, turkey roasts, etc. Most cook-in packages are available as shrink or nonshrink bags or as thermoformable roll stock. During heat processing, interaction occurs between the surface of the product and the food contact material, resulting in formation of a bond between the product and food-contacting layer of the package structure. Surlyn is typically used as this layer. Bags and/or thermoforms for cook-in products are typically multilayered structures such as nylon/Surlyn. This adhesion also helps reduce purge loss and thus increases yield. Polyesters are also used as the noncontacting layer. For turkey products with the skin on, Surlyn is not used because it adheres so strongly to the skin that upon removal of the package the skin is ripped off. Instead, modified polyolefins can be used as the food contact layer. PP can be used as the outer layer for steam cooking in a bag (Gehrke, 1985). PP functions as a heat-tolerant water barrier to protect the nylon. This type of package is normally used for thermally processing boneless turkey breasts, since the product is not cooked in a mold but is cooked on racks with live steam. During shrinkage, the film acts as the mold to form the product. Cook-in film products, especially hams, are often wrapped in a plastic netting. The plastic netting helps to maintain the mechanical integrity of the package (Harte, 1987).

Hams and other products that are repackaged following processing are generally put into nonmoisture-proof casings for cooking. They are repackaged in barrier bags made from EVA/PVDC/EVA or similar constructions using EVOH. Following vacuuming, the bags are heat-sealed or closed using various tie devices and generally put through a shrink process. A ham package being used in the United Kingdom is made from an inner tab of printed board and foil and is sandwiched between two injection-molded PP shells. The shells are sealed on the inner lip of the tub, locking the board in the middle. An inner foil lid is applied under vacuum with an outer reclosable lid of PVC applied over the top. The product has a shelf life of at least 7 mo (Anon., 1984).

Frozen, restructured products including steaks, chops, cutlets, roasts, nuggets, ribs, logs and other fabricated meats are packaged in a variety of ways. Traditionally, polyolefins (mainly PE and PVC) have predominated as overwraps for this market. Bags, pouches, trays, overwraps and PE-coated paperboard have and continue to be used extensively for these products. American Can's Bivac system (ionomer-type films) is used to skin-package fresh, processed and frozen products. Because there are no empty spaces for moisture condensation to occur, freezer burn is virtually eliminated during frozen storage. Attmore (1980) described a system in which packaging for frozen steaks

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consisted of clear polyamide (nylon) cover sheets laminated
to a coextrusion of PE and Surlyn backed by a gold-colored
layer of metallized PET. Each individual package contained
four to six individual vacuum sealed compartments. Breaded
patties, nuggets and similar breaded products are usually
packaged in PE-coated cartons. Unbreaded patties can be
packed in tray overwraps for retail display. For larger
quantities of unbreaded patties, bag-in-box packaging can
be used. In this case, PE film is wrapped between fresh
patties so that they can be easily separated, and a PE bag
is utilized to hold a convenient quantity of product, which
then goes inside a corrugated box (Harte, 1987).

Formulation Example for Restructured Red Meat Products

Restructured Flaked and Formed Beef Steaks with Soy Protein
Added

Ingredients

	Approximate Weights	
	(lb)	(oz)
Meat Ingredients		
90/10 boneless beef	58	
50/50 boneless beef	42	

Nonmeat Ingredients

Water	15	
Soy protein concentrate	3	
Salt	1	
Polyphosphate		6

Manufacturing Procedure

1. Hydrate protein concentrate in 10 lb of water.

2. Flake 90/10 beef through coarse head on high-speed-flaking machine. If low-quality or less-tender cuts of beef are used, it is advantageous to mechanically tenderize them prior to flaking.

3. Flake 50/50 beef through fine head on high-speed flaking machine.

4. Transfer all beef to mixer, add polyphosphates, and mix for 1 min.

5. Added hydrated soy protein concentrate, remaining 5 lb of water and salt; continue mixing for 3-5 min, until tacky exudate forms.

6. Chill meat to desired temperature for forming.

7. Form into desired shape.

8. Freeze individual portions, package and place in freezer storage.

(Huffman and Cordray, 1987)

Restructured Pork Snack Items (Nuggets and Sticks)

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Ingredients

	Approximate Weight		
	(lb)	(oz)	(cc)
Meat Ingredients			
Boneless leg of pork	79		
50/50 boneless pork	21		
Nonmeat Ingredients			
Water	3		
Salt		12	
Polyphosphates		6	
Optional flavorings			
Dextrose		6	
Monosodium glutamate		3	
Oleoresin black pepper			3

Manufacturing Procedure

1. Pass lean raw materials twice through a blade or rotary tenderizer.

2. Grind lean raw materials through a 3/4-in. plate.

3. Grind 50/50 pork through 1/8-in. plate.

4. Place all meat in mixer, add polyphosphate and mix 1 min.

5. Add salt, water and optional flavorings; mix 4-8 min, until tacky exudate forms.

6. Chill meat to desired temperature for forming.

7. Form in the desired shape (nugget, stick or other shape).

8. Batter, bread, flash-fry, cook, freeze, package and place in storage freezer.

(Huffman and Cordray, 1987)

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LIVESTOCK AND MEAT INDUSTRY TRENDS AND
RESTRUCTURING TECHNOLOGY FOR THE
MEAT INDUSTRY IN TAIWAN, R.O.C.

by

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AN ABSTRACT OF A REPORT

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Taiwan Province of the Republic of China increased livestock production during the past two decades. While the production of hogs, chickens, milk and hen eggs increased, cattle and goat production decreased during the past decade. Taiwanese pork consumption per capita in 1984 was about the same amount as for the U.S.A., but lamb or poultry was about 50 % and beef was about 3 % of American consumption.

Processed meat is estimated to be about 10 % of the meat consumed in Taiwan. Traditional processing methods of Chinese style meat products are highly dependent on hand-made processes that are difficult to control and mass production is difficult. The demands of more convenient and uniform processed meat products are increasing in accordance with the economic development of Taiwan. Restructured meat technologies are thus need to meet the market demands for the Taiwanese market.

Restructuring technology is not new and has historically been used to manufacture sausages. However the new concept of restructuring includes a greater variety of products. Any skeletal muscle can be restructured into a new group of consumer-ready meat products such as turkey ham, roast beef, snack sticks, beef steak, diced beef, chicken logs, corned beef logs, cured ham, chicken nuggets, pork nuggets, veal steak, chicken sticks, beef fingers and chicken patties.

Reduction of particle size is usually the first step in the restructuring process. Particle reduction methods include sectioning, chunking, grinding, slicing, flaking and chopping. The binding of meat particles is critical for the quality of restructured products. The extraction of myofibrillar proteins from meat is influenced by many factors, e.g., the state of rigor development in the meat; the ionic environment and the pH of the system;the temperature history of the meat during rigor onset; the temperature of the mix during extraction; the duration of storage of the meat; application of high pressure to the system and miscellaneous physical factors.

There are four basic types of production: (1) product is stuffed into a casing; (2) product may be placed in a forming container in which it is cooked and chilled prior to slicing or dicing; (3) product may be formed into a patty or other shape using a slide plate forming machine such as has been traditionally used for forming hamburger patties and (4) product may be formed on a cavity fill forming machine.

The bland flavor and excellent binding properties of surimi suggested that it could be used as a supplemental ingredient in restructured meat. One method of developing bind and controlling conditions prior to heat-initiated binding in fresh, frozen restructured products is to cook these products during the production process. Precooked

rolls and breaded, cooked restructured steaks, chops or nuggets, which are than frozen, are examples of this approach.

A new technology is the use of a combination of dry mixture of sodium alginate, calcium carbonate, lactic acid and calcium lactate to be added to raw meat, these materials react to form calcium alginate, a gel that holds the pieces together, whether chilled, frozen or cooked. These products may be marketed along with the solid muscle and sectioned and formed meats in chilled meat display areas.

The use of packages that provide product protection as well as enhanced convenience is critical to the successful marketing of restructured products. A rapid transfer from cooking to an efficient cooling and freezing system will aid in minimizing rancid or warm-over flavors, and should be followed by packaging under vacuum or inert gas-flushing.