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Abstract

Four experiments were conducted to assess the sensory textural properties, consumer acceptability and instrumental-sensory correlates of flaked and formed beef steaks. In Experiment 1, the effects of additions of NaCl, TPP and soy isolate on the texture of steaks were examined using a trained texture profile panel, and the texture of these steaks was compared to that of intact muscle (ribeye) steaks. Results showed large differences between the flaked and formed samples and the ribeye steak, as contrasted to small differences among the flaked and formed samples treated with different levels of NaCl, TPP and/or soy isolate.

In Experiments 2 and 3 the effect of flake size on the texture of flaked and formed beef was examined. In Experiment 2, instrumental shear data and SEM data were collected and compared to the sensory data. In Experiment 3, a comparison was made of the texture of these products to both ribeye steak and ground beef patties. Systematic differences in a variety of textural attributes were observed as a function of flake-size. In general, the smallest flake-size produced a texture most like ground beef, whereas certain intermediate and large flake sizes produced a texture most like whole-muscle steak. Simple and multiple linear regression equations were established between sensory and shear stress measures on these steaks, and these data, combined with the SEM data, suggested that tenderization of these meats is attributable to mechanical disruption of the tissue and not to an enzymatic process.

In Experiment 4, a consumer test was conducted to assess the effect of flake-size on the acceptability of flaked and formed steaks, and to assess consumer perception of the similarity of the texture of these products to other beef products. Although few significant differences in the acceptability of the flaked and formed products were observed, maximal acceptability ratings were found for the intermediate flake sizes. In addition, it was found that consumers do not associate the texture of flaked and formed steaks with any one of a variety of traditional beef products.

Introduction

In recent years the rising cost of beef has forced consumers to search for lower quality grades and cuts of beef to provide them and their families with red meat entrees. The development of the comminution method of flake-cutting has helped to close the gap between consumer desires for beef products and the amount of these products that can be borne by the family budget. This has been achieved by enabling the use of lower quality grades and cuts of beef to produce products that have the functionality and sensory properties of higher grades and cuts. As the largest single purchaser of beef and other meat products in the world, the United States military has interest in the improvement of the flaked and formed process. This interest has led to a continuing research and development program at the U.S. Army Natick Research and Development Laboratories (NLABS), aimed at improving the flaked and formed process. Over the years, research has been conducted on the ingredients, processing variables, chemical properties, rheological properties and sensory properties of flaked and formed beef, lamb, pork and veal. In the case of flaked and formed beef, one aim of this research has been to optimize the textural characteristics of the product to match that of intact-muscle steak. The present paper is a summary of recent research conducted in our laboratory on the sensory textural properties of flaked and formed beef, on their sensory—instrumental correlates, and on consumer judgments of their acceptability.

The process of flake-cutting involves impelling meat across a stationary cutting-head comprised of a circular array of cutting surfaces. After the meat has been flake-cut, a steak-like product can be prepared by mixing the comminuted meat with NaCl and sodium tripolyphosphate (TPP) and submitting the meat to a sustained pressure. Some parameters of importance in this process are the flake-size (determined by the width and spacing of blades on the cutting head), the temperature at which the meat is flaked, the levels of salt and TPP added to the mixture, the mixing temperature and time, and the pressure and temperature during forming. Of these parameters, NaCl/TPP concentration and flake-size were investigated in our laboratory for their effects on the textural properties of these products. Also, the addition of a soy isolate to improve binding of the meat was examined.

A great number of studies have examined the effects of NaCl/TPP concentration on the properties of meat (Hellendoorn, 1962; Shults and Wierbicki, 1973; Ohashi and Sugano, 1973; Shults et al., 1976; Schwartz and Mandigo, 1976; Neer and Mandigo, 1977; Theno et al., 1978; Huffman et al., 1981; Hand et al., 1981). These studies have demonstrated increased tenderness, cooking yield, water-holding capacity, cohesiveness, juiciness, flavor and acceptability of meat with the addition of NaCl and TPP at varying concentrations. In the study by Neer and Mandigo (1977) the effect of NaCl (0–3%) and TPP (0–0.5%) levels were examined in a flaked, cured pork product. They found increased cooking yield and water-binding capacity, as well as improved appearance, flavor, and acceptability with increasing NaCl levels. As TPP levels were increased, flavor desirability increased, while appearance, color and acceptability increased then decreased (Neer and Mandigo, 1977). A synergistic effect between NaCl and TPP was proposed to explain the interaction effects that resulted in a maximum acceptability at intermediate levels of both NaCl and TPP (Neer and Mandigo, 1977). This synergistic effect was observed previously by Schnell et al., (1970), Flesch and Bauer (1965), and Schwartz and Mandigo, 1976. Huffman and Cordray (1979) have reported improvements in the flavor, tenderness, juiciness and connective tissue of restructured (chunked) pork products with the addition of 0.75% NaCl, and improvements in juiciness with the addition of 0.25% TPP. However, their data show that these effects were not statistically significant. Cooking losses were decreased most by the addition of both 0.75% NaCl and 0.25% TPP. Huffman et al., (1981), working with flaked and formed patties, also found improved flavor, cohesiveness and juiciness with the addition of 0.75% NaCl, but little effect of the addition of 0.30% TPP on any measured property. They also found that the addition of NaCl and TPP improved most sensory properties of the meat more than did the addition of NaCl or TPP alone. Most recently, Hand et al., (1981) have shown improved juiciness, cohesiveness, flavor and ease of fragmentation with the addition of NaCl (0.44%), TPP (0.25%), and hydrolyzed vegetable protein (0.31%) to restructured beef steaks.

Although the addition of soy protein to beef has been frequently investigated, the addition of soy protein to flaked and formed products has only recently been studied. Claims of increased water and/or fat retention and improved binding of meat particles by addition of soy isolate (Anonymous, 1979; Schweiger, 1974; Morris, 1980) makes this a potentially important area for improving flaked and formed products. However, in a recent study by Hand et al., (1981) addition of soy protein isolate to restructured beef steaks significantly increased off-flavors, while having no effect on the sensory textural properties of the meat.

The effect of flake-size on the sensory properties of flaked and formed meat products has also not been thoroughly investigated, although the claim has been made that the "bite" of these products can be varied from a "hamburger-like" texture to a "steak-like" texture by varying the flake-size (Anonymous, 1977). In studies by Popenhagen et al., (1973) and Popenhagen and Mandigo (1978) flake-size was investigated for its effects on the sensory properties of flaked and formed pork. For products flaked at −5.6°C, significantly lower tenderness was found with a 3.0 mm than with a 6.9 mm or 12.7 mm flake-size. For products flaked at 2.2°C, significantly lower scores were found for juiciness,

cohesiveness and overall acceptability with the smallest flake-size (Popenhagen and Mandigo, 1978). Chesney et al., (1978) have also examined the effect of flake-size on the sensory properties of flaked and formed pork. In their work, they found large flake sizes (12.7 mm) to result in a product that is less cohesive than products made with smaller flake sizes (3.0 mm and 6.9 mm). Juiciness and tenderness were also found to decrease with increasing flake-size, and the overall acceptability of the products was significantly lower for the product made with the largest flake-size. At present, no studies have examined the effect of flake-size in a flaked and formed beef product, and no studies have made comparisons of the sensory characteristics of these products to an intact-muscle steak. Such information is essential for developing a flaked and formed product with steak-like texture.

General Materials and Methods

Processing of Flaked and Formed Steaks

All steaks were made from USDA Choice, yield grade 2 or 3, square-cut chucks that had been boned and trimmed of fat to 18 ± 2%. The boneless meat was tempered to 0°C and flake-cut with an Urschel Comitrol, Model 3600 (Urschel Laboratories, Inc., Valparaiso, IN 46383) using one of several specified cutting heads. The list of cutting heads is shown in Table 1, along with conformational data on each. The meat was mixed eight minutes in a ribbon-type mixer (Keebler, Chicago, IL 60636) under vacuum with salt (NaCl) and sodium tripolyphosphate ($Na_5P_3O_{10}$). The levels of salt and sodium tripolyphosphate were experimentally manipulated in Experiment 1 and held constant at 0.5% NaCl and 0.25% $Na_5P_3O_{10}$ in Experiments 2–4. The meat was stuffed into polyethylene tubing (lay-flat dimension = 13.3 cm) under vacuum (Vemeg Robot 100 S2 Type 116, Robert Pfiser and Co., Inc., Boston, MA 02210) clipped and pre-shaped to approximate the die shape. The meat log (2.7 – 3.6 kg) was frozen to −18°C and tempered to −3°C. The meat was then pressed at 8.75×10^4 N/m² in die #452 (Ribeye) using a Bettcher press, Model #70 (Bettcher Industries, Inc., Vermillion, OH 44089). The formed log was sliced on a Bettcher cleaver, Model #39 (Bettcher Industries, Inc., Vermillion, OH 44089) to produce a 6 oz. steak. The steaks were separated with patty paper, placed in sealed polyethylene bags, frozen immediately to −18°C and stored at −18°C until time of testing.

Table 1. Cutting heads used in preparation of flaked and formed steaks and conformational data about each.

Cutting Head Designation	Comitrol Designation	# of Cutting Posts on 152.4 mm Circumference	Opening Size (mm)
060	2K–020060	28	1.524
510	2J–030510	20	12.954
750	2J–030750	20	19.050
1628	2–0001600–28	28	40.640
1620	2–0001600–20	20	40.640
1614	2–0001600–14	14	40.640
1610	2–0001600–10	10	40.640

Cooking

In Experiments 1, 2 and 3, all samples were broiled from the frozen state on Farberware electric broilers, model

455N (S.W. Faber, Yonkers, NY) to an internal temperature of 69°C (internal temperature probe) turning once. In the consumer test of Experiment 4, samples were cooked on a flat grill. Details on the cooking procedure used in that test can be found in the Methods section of Experiment 4.

Sensory Panels

Texture Profile Panel. In all the experiments reported here, with the exception of Experiment 4, the flaked and formed products were evaluated by a trained texture profile panel. This panel, which consisted of 6—10 members during the period of these tests, was formed in June of 1977 and has operated within the Behavioral Sciences Division of the Science and Advanced Technology Laboratory at the U.S. Army Natick R&D Laboratories since that time. Each member of the panel was trained in the General Foods' Texture Profile Method, and all members have had extensive experience in evaluating the textural properties of a broad range of products, including fish, gelatins, breads, ground beef and other meat products.

As a descriptive/analytical panel, the first task of the panel was to develop a set of sensory attributes important for characterizing the texture of these products, as well as that of whole-muscle steak. These attributes were established through examination of a wide range of flaked and formed and whole-muscle steaks. Table 2 is a list of the important attributes and the operational definitions of each, as developed by the panel. Each attribute was evaluated at a specific time during mastication. "Coarseness" of the cooked surface was evaluated first, "springiness" was evaluated next during a partial compression with the molar teeth, "hardness," "cohesiveness" and "moisture/oil release" were evaluated during the first bite into the product, "chewiness," "size of particles," "moistness," "cohesiveness of the mass" and "amount of connective tissue" were evaluated during chewing, and "oily mouth coating" and "number of particles remaining in the mouth" were evaluated after swallowing.

Table 2: Definitions of textural attributes developed by texture profile panel for characterizing flaked and formed beef products.

Coarseness:	The perceived degree of roughness of the cut surface (characterized by large, uneven particles).
Springiness:	The perceived degree (extent) to which the sample returns to its original shape after slight compression with the molar teeth.
Hardness:	The perceived force required to compress the sample between the molar teeth.
Cohesiveness:	The perceived degree to which the sample holds together as a single mass upon biting.
Moistness:	The perceived amount of water and/or oil in the sample.
Moisture/Oil Release:	The perceived amount of water and/or oil released from the sample during mastication.
Chewiness:	The total perceived force required to reduce the sample to a consistency ready for swallowing when chewed at constant rate of force application.
Size of Particles:	The perceived volume of individual particles.
Cohesiveness of the Mass	The perceived degree to which the sample holds together as a single mass during mastication.
Amount of Connective Tissue:	The perceived volume of connective tissue (gristle) in the sample.
Oily Mouthcoating:	The perceived degree of oil left on the teeth and palate after swallowing.
Number of Particles Remaining:	The perceived number of particles left on the teeth, gums and oral cavity after swallowing.

Consumer Panel. In Experiment 4 a volunteer laboratory consumer panel was used. This panel was drawn from a population of 450 employees of NLABS who have volunteered to participate in consumer taste tests. None of

the panelists had prior experience with these flaked and formed products, although some may have had experience with commercially available flaked steaks. All panelists had participated in previous consumer acceptance tests on a variety of food products.

Experiment 1

The first experiment was designed to compare the textural characteristics of flaked and formed beef steaks to those of intact muscle steak, and to assess the effect of the addition of TPP, NaCl and soy isolate on the texture of these products.

Samples

The samples tested appear in Table 3. All were processed with the 750 (intermediate size) cutting-head (see Table 1). The tested levels of TPP were 0.0 and 0.50%, reflecting both the fact that the maximum phosphate level allowed in meat is 0.50% (U.S.D.A., 1975) and the fact that preliminary triangle tests showed no significant differences between samples with 0.25% TPP and either 0.0% or 0.5% TPP. NaCl levels of 0.0% and 0.50% were chosen on the basis of prior information concerning the necessary level for proper binding of the meat particles and on the basis of triangle tests, which showed that samples prepared with 0.0% and 0.50% NaCl were significantly different. The choice of 0.0% and 1.0% soy isolate levels was based on product usage recommendations.

Table 3: Concentrations of NaCl, TPP and soy isolate for the sample used in Experiment 1.

	Concentration (%)		
	NaCl	TPP	Soy Isolate
Treatment 1	0.0 %	0.50%	0.0%
Treatment 2	0.50%	0.0 %	0.0%
Treatment 3	0.50%	0.50%	0.0%
Treatment 4	0.0 %	0.0 %	1.0%
Treatment 5	0.0 %	0.50%	1.0%

Procedure

The five sets of samples of flaked and formed beef were prepared and cooked as described under Materials and Methods. A sixth set of samples, consisting of whole-muscle ribeye steak, was also included for evaluation and cooked in the same manner. The rib-eye cut was chosen for comparison with the flaked and formed steaks, since it is an intermediate quality cut of beef and serves as a good target product for these steaks. After cooking, samples were halved and placed on heated ceramic dishes for evaluation by the profile panel. Each member received all six samples and was instructed to evaluate them for each of the attributes listed in Table 2. All panelist judgments were made independently.

The psychophysical method of magnitude estimation was used to judge the perceived magnitude of each attribute in the products. All panelists had prior experience with this method. The ribeye sample was used as a standard and was assigned a modulus of 10.0 for each of the textural attributes. Panelists were instructed to first sample the ribeye, and to then evaluate each of the other samples relative to this standard. Panelists were instructed to assign numerical ratings according to the ratio of perceived magnitudes between the test sample and the standard. Thus, if the

chewiness of a test sample was perceived to be twice that of the standard (ribeye), the panelist would assign the number 20.0 to it; if it was one-third as chewy as the standard, he/she would assign to it the number 3.33, etc. Each sample was evaluated once for each attribute by each panelist and all test samples were evaluated in random order.

Results

The magnitude estimates assigned to each sample for each attribute were averaged across panelists by calculating the geometric mean of the magnitude estimates. The geometric mean was used, because magnitude estimates have been shown to be log-normally distributed (Stevens, 1957; Marks, 1974). Figure 1 shows the texture profiles for the three samples containing only TPP and/or NaCl. Each of the textural attributes appears along the bottom of the figure. The ordinate is the geometric mean magnitude estimate for each attribute. The solid horizontal line represents the value assigned to the standard (ribeye) steak for each attribute. The dotted horizontal lines represent 25% deviation from the standard. Although the data points for each sample reflect geometric mean ratings for different attributes, the data points have been joined to facilitate comparison of the profiles.
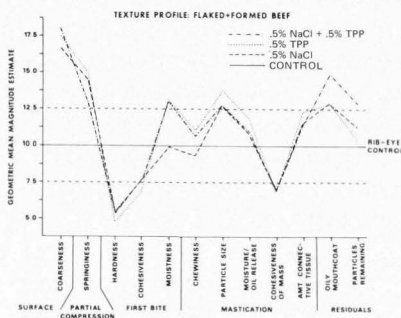

Figure 1. Texture profiles for flaked and formed beef products containing 0.5% NaCl, 0.5% TPP or 0.5% NaCl and 0.5% TPP. The ordinate is the geometric mean magnitude estimate for each texture attribute listed along the abscissa.

Overall, the profiles for the flaked and formed samples are very similar to one another, and all are quite different from that for the ribeye steak. Comparison of the logarithms of the magnitude estimates assigned to each test sample with the logarithms of the modulus assigned to the standard (Z-test) revealed that all three flaked and formed products were significantly (p<0.05) more coarse, less firm (hard), and less cohesive (during mastication) than the ribeye sample. In addition, the 0.0% NaCl/0.5% TPP sample was less cohesive (during first bite) and had greater moisture/oil release than the ribeye (p<0.05), and the 0.50% NaCl/0.0% TPP and 0.5% NaCl/0.50% TPP samples were both perceived as more oily than the ribeye sample (p<0.05). Other apparent differences

in Figure 1 were not statistically significant due to within sample variability.

Figure 2 shows the profiles for the two soy-added samples relative to the ribeye. Only the sample with both soy and TPP was significantly different from the control. This sample was significantly less firm (hard) and had more moisture/oil release and more particles remaining after swallowing than the ribeye sample (p<0.05).
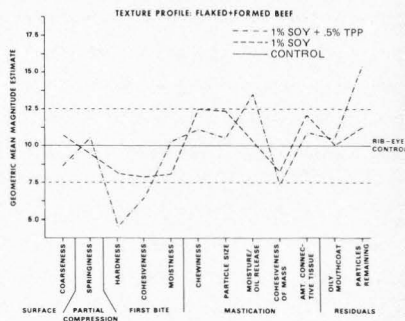

Figure 2. Texture profiles for flaked and formed beef products containing 1% soy isolate or 1% soy isolate and 0.5% TPP.

Figure 3 is a composite of Figures 1 and 2, showing the similarity among all of the five flaked and formed products. Analysis of variance applied to the logarithms of the magnitude estimates assigned to the five test samples showed no significant differences among any of the flaked and formed products treated with different levels of NaCl, TPP and soy isolate.
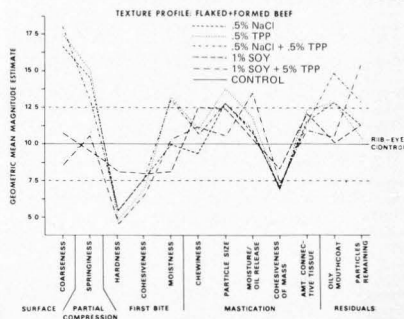

Figure 3. Composite of Figures 1 and 2.

Discussion

The texture profiles shown in Figures 1–3 provide useful information from which one can assess the textural differences between the flake-cut beef products of this test and intact muscle (ribeye) steak. The small differences among the five different flaked and formed samples suggest that variations in the levels of NaCl and TPP between 0 and 0.5% produce only slight differences in the texture of these products, as compared to the differences observed between these products and intact muscle steak. The failure to find significant effects of NaCl and TPP level on the texture of these products is surprising in light of previous research, but is consistent, for example, with the failure to find significant effects of these ingredients in restructured pork (Huffman and Cordray, 1979).

In view of the fact that all of the samples with 0.50% TPP had higher geometric mean ratings for moistness and moisture/oil release than the control (Figure 3) and moisture/oil release was significantly higher for the 0.0% NaCl/0.50% TPP and the 1.0% soy isolate/0.50% TPP samples than for the control, it was decided that the level of TPP could be reduced below 0.50%. Since the binding properties of the meat during processing were adequate with 0.25% TPP addition, 0.25% TPP was selected for use in subsequent processing of these products.

The fact that the sample with only 1.0% soy isolate produced a texture that was no different from the NaCl and TPP-added samples, suggests that the soy-isolate assisted in the binding of the meat flakes, as has been suggested previously (Morris, 1980; Anonymous, 1979). In addition, since some improvement was observed in the coarseness and springiness of the soy-isolate-added samples (Figure 3), reason exists for giving further study to the addition of soy isolates to these products.

Experiment 2

The second major processing variable having direct influence on the textural properties of flaked and formed products is flake-size. This experiment was designed to provide information on the magnitude of these effects using three greatly different flake sizes. Both sensory and instrumental (Instron shear tests and scanning electron microscopy (SEM)) data were collected.

Samples

Samples of flaked and formed beef processed with three different cutting heads were used as test products. Cutting heads were chosen to enable a comparison of the two extreme flake sizes with the flake-size used in preparing the samples in Experiment 1. The three cutting heads chosen for testing were the 060 (small flake), 750 (intermediate flake) and 1610 (large flake).

Procedure

Samples were cooked, prepared and served in the same manner as in Experiment 1, except for certain instrumental measures that were made on raw samples, as described below.

Sensory Data. The textural attributes evaluated were reduced from the 12 used in Experiment 1 to include only the mechanical properties perceived during partial compression, first bite and mastication. The surface and residual properties were not evaluated, because they were not deemed important to the differentiation of these three products. The attributes of moisture/oil release and cohesiveness of the

mass were found to be redundant with the moistness and cohesiveness attributes, respectively, and so they were also eliminated.

Samples were presented simultaneously to members of the texture profile panel and all ratings were made independently of one another. The method of magnitude estimation was used and the sample processed with the 750 head-size was designated as the standard and assigned the number 100.0 on all attributes. Panelists evaluated the 750 head-size first and then evaluated the other two samples in random order. Five replicates were conducted.

Shear Data. The punch shear data were obtained with an Instron Universal Testing Machine equipped with a Punch and Die test cell (Segars et al., 1975). A 2 cm diameter flat-end punch travelling at 5 cm/min was forced through the cooked steak and maximum shear stress (punch shear), stress at yield, energy to rupture and stiffness were determined from the resulting force-deformation curves.

SEM Data. Small pieces of meat approximately 1 cm³ were cut from an area adjacent to where the Instron punch had passed through the sample and were put into 2.5% glutaraldehyde fixative overnight (approximately 16 hrs). The pieces were then cut into smaller 0.2 cm³ pieces and stored in the fixative for 24 hrs. Samples were then dehydrated through 100% ethyl alcohol and critical point dried using liquid CO_2.

The dried samples were mounted on specimen stubs with conductive silver paint, sputter coated with gold-palladium, and then examined in a Nanometrics SEM at 20 kV. Polaroid type 55 film was used.

Results

Sensory Data. Figure 4 shows the geometric mean magnitude estimates assigned to each sample for each attribute. The attribute ratings for the sample processed with the 750 head-size are all designated by a single point at 100.0 on the ordinate, representing the modulus (standard number) assigned to that sample.

In order to test whether ratings for the samples processed with either the 1610 or 060 head-size were significantly different from that of the 750 head-size, the magnitude estimates were normalized by taking the logarithm of the values, and the normalized values were then used to statistically test the hypothesis that they did not differ from a value of 2.0 (log of 100). The results of these Z-statistics (two-tailed) are shown by the brackets in Figure 4, which show the attribute ratings that were found to be significantly different from 100 ($p < 0.05$).

The sample processed with the 1610 head-size had ratings significantly above 100 for all attributes except "moistness." In contrast, the sample processed with the 060 head-size had attribute ratings significantly below 100 for the attributes of "cohesiveness," "chewiness," "size of particles," and "amount of connective tissue."

Shear Data. Data from the Instron Punch and Die tests are shown in Table 4. The maximum shear stress, stress at yield and energy to rupture all reflect the effort required to cause separation and tearing of the meat structure. In general they reflect the "toughness" of the meat and show increases as flake size increases. Standard deviations are also included and show an increase as flake size increases. A previous study (Segars et al. 1983; unpublished manuscript) has demonstrated a linear relationship between the mean and standard deviation of maximum shear stress data; the data in Table 4 also show this linear relationship.
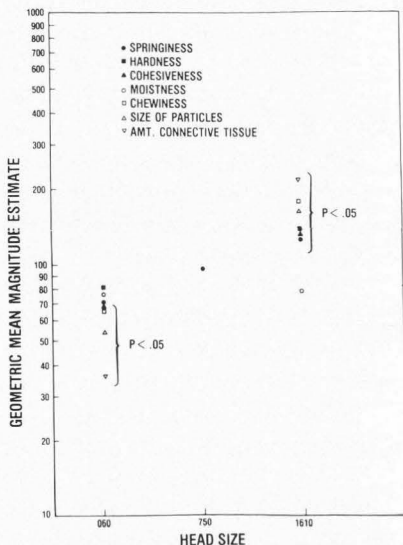
Figure 4. Geometric mean magnitude estimates of seven textural attributes for flaked and formed beef prepared with the 060 and 1610 cutting head sizes. Data are compared to a modulus of 100.0 that was assigned to represent the intensity of each attribute for a product made with the 750 head size.

The stiffness parameter, also in Table 4, reflects the initial firmness or resistance to indentation of the steak, and it is much less affected by flake size than either the maximum shear stress, stress at yield or energy to rupture. Although the initial firmness of the steaks does not change significantly with flake size, it is lowest with the intermediate flake size.

Table 4. Means ± standard deviations for Instron punch and die shear data obtained from the samples tested in Experiment 2

Head Size	n	Maximum Shear Stress N/cm^2	Stress At Yield N/cm^2	Stiffness N/cm^2	Energy To Rupture N/cm
060	16	5.822 ± 0.690	5.770 ± 0.732	10.966 ± 2.492	3.475 ± 0.897
750	16	8.404 ± 1.362	7.023 ± 1.496	9.871 ± 1.060	6.977 ± 0.604
1610	16	12.172 ± 1.895	10.499 ± 2.233	12.175 ± 1.349	8.828 ± 1.269

SEM Data. Scanning electron micrographs representing the three products in both raw and cooked states are shown in Figure 5.

Samples a and d in Figure 5 were prepared from meat cut with the 060 cutting head, meat for samples b and e was cut with the 750 cutting head and the meat for samples c and f was cut with the 1610 cutting head. Samples a, b and c were raw, samples d, e and f were cooked.

Discussion

Sensory Data. Overall, the sensory data demonstrate an increase in the "springiness," "hardness," "cohesiveness," "chewiness," "size of particles," and "amount of connective tissue" for flaked and formed beef products processed with increasingly larger cutting heads. Moreover, the magnitude of these differences were on the order of 6 to 1 for some attributes, e.g., amount of connective tissue. These data underscore the importance of flake-size in establishing a desired texture for flaked and formed products.

Shear Data. The instrumental shear measurements (Table 4) show that the products become firmer and less homogeneous as flake size increases. Increases in the maximum shear stress, stress at yield, and energy to rupture reflect a toughening of the meat, and are, therefore, in agreement with the sensory data.

SEM Data. The field of view shown in the micrographs of Figure 5 is approximately 100 micrometers wide. The scale of flake sizes, even for the smallest flakes produced with the 060 cutting head, is approximately 1500 micrometers in its largest dimension. Thus the photographs represent only one-tenth of the surface of the smallest flakes, and effects from macroscopic changes (flake size) should not be visible in the pictures. Any effects observed would presumably stem from secondary effects caused by differences in the quantity of enzyme released and changes in the amount of surface area available for enzymatic action. Both quantities should be greatest for the smallest flakes (060), since these flakes required the greatest amount of cutting. Hence the 060 samples should show the greatest amount of structural damage or interruption of the normal state. This damage might be expected to decrease progressively as the flake size increases.

The micrographs of Figure 5 do not show distinct change in the fiber due to interruption or other structural damage as flake size is altered. It thus appears that enzymatic breakdown of the meat tissue is not affected by the flaking process, either because the released enzymes have not reached a level sufficient to produce observable structural changes, or under the experimental processing conditions, the enzymes had neither the time nor the proper environment in which to act. In any case it seems that the tenderization produced by the flaking process is due, in this experiment, primarily to a mechanical disruption and breaking of the connective tissue and muscle fibers. The more disruption and breakage that occurs from mechanical means, the more tender the product.

In Experiment 1 of this report, whole muscle rib-eye steaks were compared to flaked and formed steaks. In that experiment, the hardness and cohesiveness of the flaked and formed product (made using the 750 cutting head) were lower and the chewiness was greater than in the rib-eye steak. In the next experiment to be reported (Experiment 3), flaked and formed steaks made with seven different cutting heads, ground beef, and rib-eye steaks were evaluated on the same three sensory attributes. The textural changes occurring with increasing flake size paralleled the changes observed in the present experiment.
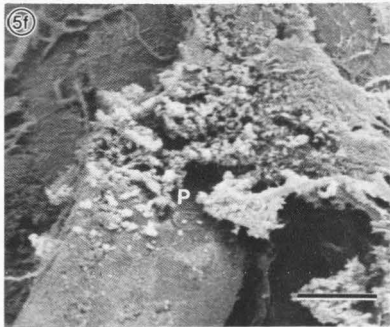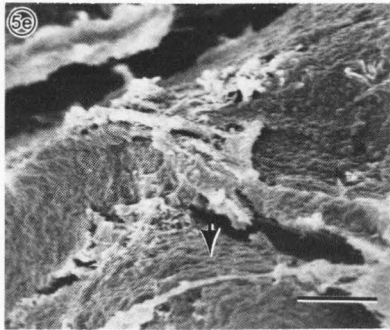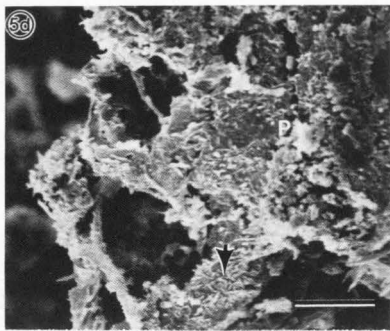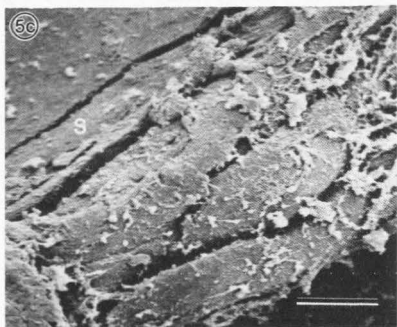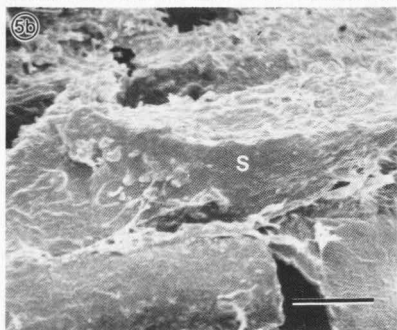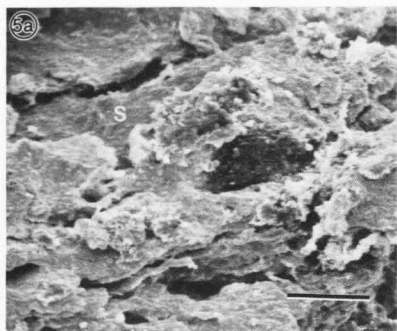
Figure 5. SEM micrographs of raw samples used in Experiment 2. 5a, 5b and 5c were processed with the 060, 750 and 1610 cutting heads, respectively. The muscle fiber surface (S) appears normal. Bar = 20μm.

Figure 5. (cont'd). SEM micrographs of cooked samples used in Experiment 2. 5d, 5e and 5f were processed with the 060, 750 and 1610 cutting heads, respectively. Heat causes coagulation (P) and degradation (arrows) of the muscle fiber surface. Bar = 20μm.

Although the discrepancy between chewiness judgments, on the one hand, and hardness and cohesiveness judgments, on the other, may seem perplexing, it can be explained on the basis of the fact that chewiness is evaluated throughout the mastication process, and is, therefore, greatly influenced by the textural characteristics of the individual pieces of meat within the sample.

The attributes of hardness and cohesiveness are evaluated only upon first bite and, thus, are much less affected by the texture of the individual pieces of meat in the sample. Since the SEM studies in this experiment showed that the individual pieces were not visibly affected by the flaking process, one would then expect that the chewiness of flaked and formed steaks, which are made from the tougher meat of square-cut chuck, would be greater than the chewiness of rib-eye steaks. This was, in fact, what was found.

The conclusions from the present study are that flake size has a significant effect on the texture of flaked and formed meat and that natural chemical or enzymatic action plays only a minor role in the tenderization of flaked and formed meats. The major role in tenderization is played by the mechanical disruption itself. This stands in contrast to a previous study of flaked and formed meat (Cohen et al., 1982) which showed that various textural parameters, including amount of connective tissue, were improved with the addition of lysosomal proteolytic enzymes (cathepsins) during preparation. In that study, enzymes were added to an already flake-cut meat, which issued a much higher enzyme level than in the present study. These high enzyme levels, coupled with a longer mixing time of 15 minutes (8 minutes was used in the present study), could explain why the effect of enzyme was found only in the previous work. This suggests that the present processing methods for flaked and formed products could be modified (longer mixing times, holding at enzyme active temperatures etc.) to take advantage of the tenderization offered by the small amounts of natural enzymes released during the flaking process.

Experiment 3

Experiment 3 was aimed at a parametric examination of the effects of flake-size on the texture of flaked and formed beef and a comparison of these products to ground beef and ribeye steak. In addition, the relationship between sensory and instrumental measures of these products was assessed by obtaining Instron punch-shear data (maximum shear force, maximum strain and stiffness) and single blade shear (Food Technology Corp, Rockville, MD 20852) data (force per unit area) on these samples.

Samples

The samples consisted of seven treatments of flaked and formed beef, one sample of ribeye steak and one sample of ground beef. The flaked and formed beef samples were all processed as described under Materials and Methods, except that each set of samples was processed with a different cutting head. Table 1 lists the seven cutting-head sizes that were used. The ground beef was prepared from similar meat, ground through a 3.175 mm plate, stuffed into casings (with no salt or TPP), pressed, sliced and packaged in the same manner as the flaked and formed samples.

Procedure

Samples were cooked, prepared and served in the same manner as described in the previous experiments. Since test-

ing of these products was to continue for an extended period and no suitable sensory reference standards were available for these products, it was necessary to identify a simple and reliable scalar method that could be used to evaluate these products without the need for an invariant reference. A 7—point category scale method was chosen for this purpose. Of the seven points, three were labeled. The three labeled points were 1—slight, 4—moderate and 7—extreme. Zeros were allowed to reflect absence of an attribute in the sample.

Samples were presented randomly to panelists over several sessions. During each session, three samples were presented. Each panelist rated each sample on the same attributes used in Experiment 2. In addition, two visual attributes were judged. These were the "coarseness of the cut surface" and the "size of fat deposits on the cooked surface." All samples were evaluated on five separate occasions by each panelist.

Results

The mean panel ratings for each sample and each attribute were calculated and appear in Table 5. Analysis of variance performed on the data revealed significant effects ($p<0.01$) of cutting-head size on all of the judged attributes. These results, as well as the results of Neuman—Keuls contrast tests performed on the differences in mean ratings among samples are shown in Table 5. In order to visually compare the mean ratings of the flaked and formed products to the ratings assigned to the ribeye, a difference score was calculated for each sample. The difference score was the mean panel rating assigned to the test sample minus the mean panel rating assigned to the ribeye sample. Thus, a score of zero represents identity with the ribeye steaks, scores greater than zero indicate that the sample had more of the attribute than the ribeye, and scores less than zero indicate that the sample had less of the attribute. These difference scores were plotted by attribute and appear in Figures 6—8. Figure 6 is a plot of the scores for the visual attributes of "coarseness" and "size of fat deposits," Figure 7 is a plot of the mechanical attributes and Figure 8 is a plot of the geometric and moisture attributes.

Figure 6 shows a steady increase in the "perceived size of fat deposits" on the cooked surface of these products, starting with ground beef and progressing through increasing flake sizes. In all cases the size of fat deposits is smaller for the flaked and formed products than for ribeye steak, although the 1614 and 1610 head sizes were not significantly smaller (Table 5). A large difference can be seen between the "coarseness" of the flaked and formed product processed with the smallest cutting-head (060) and those processed with larger head sizes. Ground beef was significantly more coarse than any of the flaked and formed samples (Table 5) and all of the flaked and formed products were more similar in coarseness to the ribeye steak than to ground beef.

Figure 7 shows a steady increase in the perceived "hardness," "chewiness," "cohesiveness upon first bite," and "cohesiveness of the mass" in progressing from ground beef through increasing flake (cutting-head) sizes of the flaked and formed products. The "springiness" of the products, however, tended to decrease with increasing head-size. Both ribeye and ground beef were significantly less springy than any of the flaked and formed products (Table 5).

Figure 8 shows an increase in both the "amount of connective tissue" and the perceived "size of chewed pieces" with increasing head-size in the flaked and formed products.

In both instances a greater increase is observed within the smaller head sizes. Also, in both instances, ground beef falls between the smallest (060) head-size and the others. The "moisture/oil content" of the samples did not vary greatly among any samples, showing few significant differences (Table 5).

Table 5. Mean ratings assigned to each sample on each attribute and results of ANOVA's and Neuman-Keuls contrasts tests for the data obtained in Experiment 3. Mean ratings in the column with the same superscript (a,b,c,d,e) are not significantly different (p<.05)

Coarseness		Size of Fat Deposits	
Ground Beef	5.69[a]	Rib-Eye	5.66[a]
1620	4.31[b]	1614	4.93[ab]
1610	4.00[b]	1610	4.78[ab]
1614	3.87[b]	1620	4.13[bc]
510	3.80[b]	750	3.36[cd]
Rib-Eye	3.05[bc]	1628	3.13[cd]
750	3.00[bc]	510	2.40[de]
1628	2.20[cd]	Ground Beef	1.50[e]
060	1.73[d]	060	1.45[e]

Springiness		Hardness	
060	5.45[a]	1610	5.33[a]
750	4.64[ab]	Rib-Eye	4.77[ab]
1620	4.63[ab]	1614	4.60[ab]
1628	4.40[ab]	750	4.36[ab]
510	4.20[b]	1628	4.27[ab]
1614	4.07[b]	1620	4.19[ab]
1610	3.67[b]	510	4.13[ab]
Ground Beef	2.56[c]	060	3.60[bc]
Rib-Eye	1.66[d]	Ground Beef	2.69[c]

Cohesiveness		Chewiness	
Rib-Eye	6.16[a]	1610	6.11[a]
1610	5.22[ab]	1614	5.73[a]
1614	4.80[b]	1620	5.50[a]
750	4.55[b]	750	5.18[ab]
1620	4.50[b]	1628	5.00[ab]
1628	4.47[b]	510	4.47[b]
510	4.33[b]	Rib-Eye	4.44[b]
060	3.70[b]	060	4.10[b]
Ground Beef	2.44[c]	Ground Beef	3.25[c]

Size of Chewed Pieces		Moistness	
Rib-Eye	5.95[a]	1620	5.19[a]
1610	5.67[ab]	1614	5.13[a]
1614	5.27[ab]	1628	4.87[ab]
750	5.09[ab]	510	4.87[ab]
1620	4.88[b]	750	4.82[ab]
1628	4.67[bc]	1610	4.78[ab]
510	4.20[bc]	060	4.60[ab]
Ground Beef	3.69[c]	Rib-Eye	4.00[b]
060	2.30[d]	Ground Beef	3.81[b]

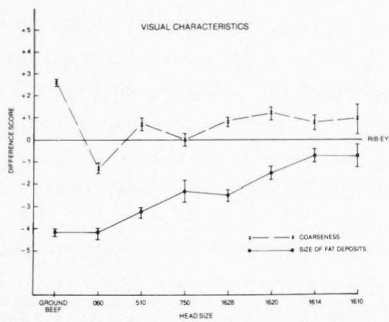| Cohesiveness of Mass		Amount of Connective Tissue	
Rib-Eye	5.51[a]	1610	5.89[a]
1610	5.11[a]	1614	5.67[a]
1614	4.93[a]	1620	5.19[a]
1620	4.06[b]	510	3.87[b]
750	3.73[bc]	750	3.73[b]
1628	3.40[bc]	1628	3.40[b]
510	3.40[bc]	Ground Beef	2.40[c]
060	2.90[c]	Rib-Eye	2.13[cd]
Ground Beef	1.63[d]	060	1.30[d]

Figure 6. A plot of difference scores for the two visual attributes judged in Experiment 3. The difference score is the rating assigned to the test sample minus the rating assigned to the ribeye control.
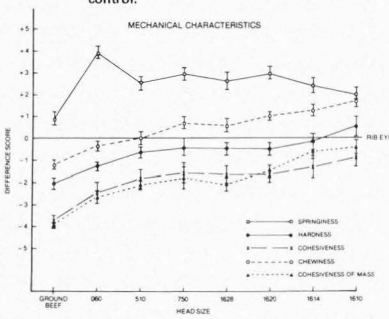

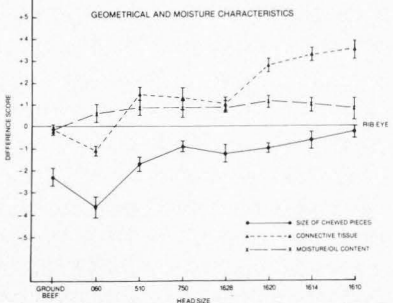Figure 7. Same as Figure 6, but for the mechanical texture attributes.

Figure 8. Same as Figure 6, but for the geometrical and moisture attributes.

Table 6 shows Spearman rank-order correlation coefficients for the relationships between head-size and each of the judged sensory attributes. Significant positive correlation coefficients were observed for all sensory attributes except "springiness," which shows a non-significant negative correlation with cutting-head size.

In order to index the degree of similarity of each flaked and formed sample to the ribeye control, the average absolute deviation of the mean ratings for each test sample from the control was calculated across all attributes. These average deviations appear in Table 7. As can be seen, the smallest absolute deviations were found for the 1610, 1614, and 750 cutting-head sizes.

Although the 1610 and 1614 cutting heads produced samples that were very similar to one another on all attributes, these two samples differed greatly from the 750. Examining Figure 6, one can see that the visual appearance of the samples prepared with the 750 cutting head were different from those prepared with the 1614 and 1610 cutting heads, the former having smaller fat deposits on the cooked surface and looking less similar to ribeye steak. Similarly, Figure 7 shows that the samples processed with the 750 head-size were less like the control in cohesiveness. On the other hand, the 750 is more similar to the control than either the 1610 or 1614 on the attributes of chewiness (Figure 7) and amount of connective tissue (Figure 8). Thus, while all three samples are about equally similar to the control, they are similar on different sensory dimensions.

Table 8 shows the Pearson product-moment correlation coefficients among all pairs of judged sensory attributes. As can be seen, the visual attribute of "coarseness," as well as those of "springiness" and "moisture/oil content," were not significantly correlated with any other sensory attribute. On the other hand, the visual attribute of "size of fat deposits" had a significant positive correlation with "hardness," "cohesiveness," "size of chewed pieces," and "cohesiveness of the mass." In addition, "hardness" was significantly correlated with "cohesiveness," "chewiness," and "cohesiveness of the mass," "cohesiveness" was significantly correlated with "amount of connective tissue," and the "size of chewed pieces" was significantly correlated with "cohesiveness of the mass."

Table 9 shows the Pearson product-moment correlation coefficients between the four instrumental texture measures obtained on these products and each of the mechanical, geometric and moisture/fat-related sensory attributes. As can be seen, maximum strain (E) was not significantly correlated with any attribute. The stiffness (S) of the products had a significant (p<0.01) negative correlation with perceived "springiness." Maximum shear stress (γ) had significant positive correlations with "cohesiveness," "cohesiveness of the mass," and with the "size of the chewed pieces," while maximum shear force per unit area (F) was only significantly correlated with the "size of the chewed pieces."

Table 10 shows the multiple linear regression equations and multiple correlation coefficients (R) for predicting each of the sensory texture attributes from the instrumental measures obtained on the products. Improvements in the correlation coefficients over the simple linear coefficients can be observed for all attributes except "springiness" and "size of chewed pieces," for which the simple linear correlations with (S) or (F), respectively, are as high.

Discussion

The above data show the significant effects that flake-size can have on the perceived texture of flaked and formed beef products. For optimizing the texture of these products to that of an intact muscle steak, e.g., ribeye, these data suggest that either the 750 cutting-head or the 1610 and 1614 cutting heads are most suitable, albeit for different reasons. If the appearance or cohesiveness of the product is to be matched, then the 1610 or 1614 head sizes are better choices. If the chewiness or the amount of connective tissue is to be matched, then the 750 head-size is more suitable. The decision, while difficult, must necessarily take into account the acceptability of the products processed by these head sizes, since some one or combination of these textural attributes may be more important than others in affecting acceptability (see Experiment 4).

The correlation coefficients in Table 8 show a strong linear association between the sensory attributes of "hardness," "chewiness," "cohesiveness," and "cohesiveness of the mass." These correlations are indicative of an underlying perceptual factor that may be termed "toughness." The visual attribute of "size of fat deposits" is also linearly associated with these attributes, reflecting the fact that fat or connective tissue perceived visually in the products are also perceived by the oral-tactile sense. In contrast to the above, all other judged dimensions are relatively independent.

The simple linear correlation coefficients between sensory and instrumental measures suggest that the Instron maximum shear force (γ) may be used alone to predict either the "cohesiveness," "cohesiveness of the mass" or "size of

Table 6. Spearman rank-order correlation coefficients for the relationship between cutting-head size and each of the judged textural attributes of the products.

ATTRIBUTE

Size of fat deposits on cooked surface	0.96**
Coarseness of cut surface	0.86*
Springiness	-0.75
Hardness	0.96**
Cohesiveness	0.89*
Chewiness	0.96**
Size of chewed pieces	0.89*
Moisture/oil content	0.86*
Cohesiveness of the mass	0.96**
Amount of connective tissue	0.86*

** p<0.01
* p<0.05

Table 7. Average absolute deviation of the mean ratings for the flaked and formed and ground beef samples from the mean ratings for the ribeye sample. deviations are averaged across all sensory attributes.

Sample	Average Absolute Deviation
Ground beef	2.13
060	2.13
510	1.53
750	1.29
1628	1.41
1620	1.56
1614	1.24
1610	1.20

Table 8. Pearson product—moment correlation coefficients among all pairs of sensory attributes.

	Size of Fat Deposits	Springi-ness	Hard-ness	Cohesive-ness	Chewi-ness	Size of Chewed Particles	Moisture/ Oil Content	Cohesive-ness of Mass	Amount of Connective Tissue
Coarseness	0.01	-0.47	-0.28	-0.35	-0.12	0.19	-0.25	-0.19	0.32
Size of Fat Deposits		-0.40	0.83**	0.88**	0.69	0.91**	0.20	0.95**	0.60
Springiness			-0.04	-0.25	0.28	-0.50	0.74*	-0.24	0.12
Hardness				0.91**	0.85**	0.77	0.45	0.93**	0.65
Cohesiveness					0.62	0.77	0.23	0.95**	0.39
Chewiness						0.64	0.76	0.73	0.89**
Size of Chewed Particles							0.14	0.80**	0.64
Moisture/Oil Content								0.30	0.69
Cohesiveness of Mass									0.56

$* \; p < 0.05$
$** \; p < 0.01$

Table 9. Pearson product—moment correlation coefficients between the instrumental and sensory texture measures.

	Springiness	Hardness	Cohesiveness	Chewiness	Size of Chewed Particles	Moisture/0.1 Content	Cohesiveness of Mass	Amt Connective Tissue
E	0.68	-0.47	-0.74	-0.04	-0.57	0.43	-0.68	0.12
S	-0.82**	0.26	0.53	-0.05	0.53	-0.50	0.52	-0.06
γ	-0.43	0.75	0.83**	0.60	0.89**	0.23	0.87*	0.61
F	-0.42	0.50	0.58	0.48	0.80**	0.17	0.67	0.61

$* \; p < 0.01$ $** \; p < 0.05$

Table 10. Multiple Linear regression equation coefficients and multiple correlation coefficients relating the instrumental texture measures to the sensory texture measures.

	E	S	γ	F	(c)	R
Springiness	1.906	-0.468	0.346	-0.100	3.967	0.85
Hardness	-6.415	-0.259	0.671	-0.137	8.912	0.94
Cohesiveness	-13.544	-0.267	0.752	-0.157	15.848	0.99
Chewiness	2.271	-0.278	0.726	-0.099	-0.118	0.87
Size Chewed Pieces	-3.371	-0.093	0.497		3.840	0.89
Moisture/Oil	3.711	-0.176	0.355	-0.051	0.015	0.93
Cohesiveness of Mass	-11.990	-0.267	0.817	-0.130	12.471	0.96
Amt Connective Tissue	20.361	-0.211	1.012	-0.022	-23.592	0.92

chewed particles" of the samples, and that the instrumental stiffness (S) of the sample may be used to predict its perceived springiness. Similarly, force per unit area (F) measures (from the Food Technology Corporation shear data) may also be used to predict the size of chewed particles. However, by using a multiple regression formula (Table 10), better predictive relationships can be established for most of the sensory attributes.

Experiment 4

Experiment 3 was aimed at identifying the similarities and dissimilarities in the textural properties of the flaked and formed products processed with different cutting heads and their relationship to whole-muscle steak. The present experiment was aimed at identifying which, if any, of the flaked and formed samples was most acceptable to consumers and how the acceptance of these products compared with ground beef or ribeye steak.

Samples

The same test samples as used in Experiment 3 were employed.

Procedure

The samples were cooked on a flat grill, preheated to 177°C and cooked to an internal temperature of 69°C. This method of cooking was chosen since it is the method that is used in most military dining halls.

The consumer panel was comprised of volunteer employees of the Food Acceptance Laboratory taste test panel. None of these panelists had prior experience with the flaked and formed products, although all had participated in previous acceptance tests with other products.

Fifty (50) randomly selected consumer panelists participated in each of the three test sessions. During each session, three of the nine test samples were presented for evaluation. Samples were presented randomly and sequentially to each panelist on preheated ceramic plates. All tests were conducted in individual light-controlled (white fluores-
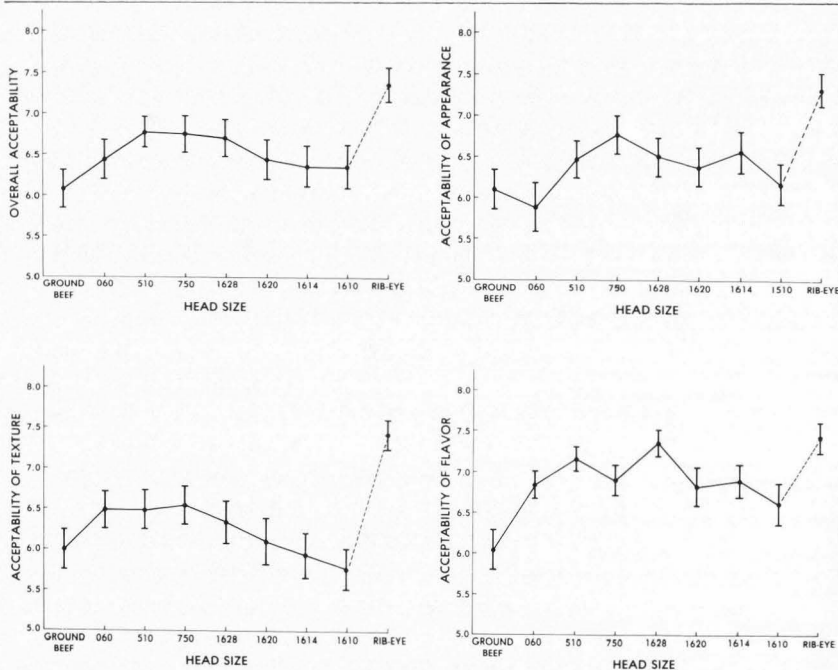

Figure 9. Mean ratings of "overall acceptability" (top, left), "acceptability of appearance" (top, right), "acceptability of texture" (bottom, left) and "acceptability of flavor" (bottom, right) for the flaked and formed beef products, ground beef patty and ribeye steak used in Experiment 4.

cent) sensory testing booths.

Panelists were asked to rate each sample for its "overall acceptability," "acceptability of texture," "acceptability of appearance" and "acceptability of flavor." A 9—point labeled hedonic scale was used. In addition, each panelist was asked to indicate on a printed ballot, whether the texture of the sample was most like that of "hamburger," "salisbury steak," "cubed steak," "swiss steak," or "ribeye or other intact muscle steak." A choice of "other" was also provided. The only information provided to the panelists was that they would be evaluating samples of "100% beef."

Results

The mean ratings obtained for each of the nine test samples on each of the judged attributes are shown in Figure 9. As can be seen, on "overall acceptability," all of the flaked and formed products were rated more acceptable than ground beef, but less acceptable than ribeye steak. Maximum acceptability was observed for the 510, 750 and 1628 head sizes. For "acceptability of texture" all of the flaked and formed samples were less acceptable than the ribeye, but, in addition, several of the largest head sizes were less acceptable than ground beef. The most acceptable texture among these samples was observed for the 060, 510, and 750 head sizes. On "acceptability of appearance" all of the flaked and formed samples were less acceptable than the ribeye steak and the 060 was less acceptable than ground beef. The most acceptable in appearance of the flaked and formed products was the sample prepared with the 750 cutting-head. "Acceptability of Flavor" showed lower mean ratings for the flaked and formed products than for the ribeye, but all flaked and formed samples were more acceptable than ground beef. The latter effect may be partly due to the absence of salt in the ground beef sample. The 1628 head size produced the most acceptable flavor.

Table 11 shows the results of analyses of variance and Neuman—Keuls contrast tests conducted on these data. Significant effects were found for all four of the judged attributes. Neuman—Keuls contrasts revealed that the 510, 750, and 1628 head sizes were not significantly different from the ribeye steak on "overall acceptability," although they were also not significantly different from those made with other head sizes or from ground beef. For "acceptability of appearance," only the 750 head-size was not significantly different from the ribeye, although again, it was not significantly different from any other flaked and formed sample or ground beef. Concerning the "acceptability of texture," all flaked and formed products were significantly less acceptable than the ribeye sample, but none differed from any other test sample. Lastly, none of the flaked and formed products were significantly more acceptable than ground beef.

Figure 10 is a plot of the responses to the question asking about the similarity of the texture of the samples to various alternative cuts of meat. As can be seen, ground beef was "correctly" described as having a texture like that of "hamburger," and ribeye steak was "correctly" identified as "ribeye or some other intact muscle cut of meat." However, there was little agreement concerning the texture of the flaked and formed products. These products were randomly categorized as being like hamburger, ribeye steak, salisbury steak, etc.

Discussion

It is clear from the data that most of these flaked and formed beef products differed significantly from both ribeye steak and from ground beef patties. Based on the mean ratings of "overall acceptability," it would appear that intermediate flakes sizes (510, 750, 1628) produce the most acceptable products, although statistically significant differences between these samples and samples processed with other head sizes are not apparent. Notably, the acceptability of these products does not differ from intact muscle ribeye steak.
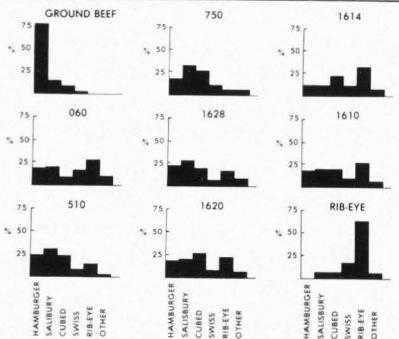
Table 11 : Results of consumer tests conducted on flaked and formed beef in Experiment 4. Mean ratings in the same column with the same superscript (a,b) are not significantly different (p < 0.005).

Overall Acceptability

ANOVA:

F= 2.98, df = 8,392 p < 0.01

Neuman-Keuls Contrasts:

$S_{\bar{y}}$ = 0.0457   0.05 criterion = 0.1966

Rib-Eye	7.36[a]
510	6.78[ab]
750	6.74[ab]
1628	6.70[ab]
060	6.44[b]
1620	6.44[b]
1614	6.36[b]
1610	6.36[b]
Ground beef	6.06[b]

Acceptability of Appearance

ANOVA:

F= 3.78, df = 8,392 p < 0.01

Neuman-Keuls Contrasts:

$S_{\bar{y}}$ = 0.0475   0.05 criterion=0.2046

Rib-Eye	7.34[a]
750	6.78[ab]
1614	6.56[b]
1628	6.50[b]
510	6.46[b]
1620	6.38[b]
1610	6.18[b]
Ground beef	6.10[b]
060	5.88[b]

Acceptability of Texture

ANOVA:

F=4.66, df=8,392 p < 0.01

Neuman-Keuls Contrasts:

$S_{\bar{y}}$=0.0513 0.05 criterion=0.2207

Rib-Eye	7.42[a]
750	6.54[b]
060	6.48[b]
510	6.48[b]
1628	6.34[b]
1620	6.10[b]
Ground beef	6.00[b]
1614	5.94[b]
1610	5.76[b]

Acceptability of Flavor

ANOVA:

F=4.76, df=8,392 p < 0.01

Neuman-Keuls Contrasts:

$S_{\bar{y}}$=0.0367 0.05 criterion=0.1576

Rib-Eye	7.44[a]
1628	7.36[a]
510	7.16[a]
1614	6.90[a]
750	6.90[a]
060	6.84[a]
1620	6.84[a]
1610	6.62[a]
Ground beef	6.04[a]

Figure 10. Percentage of consumers characterizing the texture of each of the test samples in Experiment 4 as "hamburger," "salisbury steak," "cubed steak," "swiss steak," "ribeye steak or other intact muscle steak" or "other."

The results shown in Figure 10 suggest that consumers do not perceive flaked and formed beef steaks as either intact-muscle cuts of meats or as hamburgers. Neither do they uniformly describe them as salisbury, cubed or swiss steak. Rather, it appears that consumers perceive these products as entirely new beef products. These data suggest that flaked and formed steaks should be marketed as an entirely new meat product, rather than as a substitute for existing products.

Summary and Conclusions

The studies reported here provide information on the effects of NaCl, TPP, soy isolate and flake-size on the sensory-instrumental texture properties, microstructure and/or consumer acceptability of flaked and formed beef products.

Results of this research show that flake-size has a more important effect on the perceived texture of flaked and formed products than does the addition of NaCl, TPP, or soy isolate. In particular, flake-size was shown to be significantly correlated with the hardness, cohesiveness, chewiness, moisture/oil content, cohesiveness of the mass, amount of connective tissue and size of chewed pieces, as well as with such visual attributes as the "size of fat deposits on the cooked surface" and the "coarseness of the cut surface." Taking all attributes together, the 750 head-size and the 1610 and 1614 head sizes produced products most similar to ribeye steak. The effects of the addition of various combinations of 0% and 0.5% NaCl, 0% and 0.5% TPP and 0% and 1% soy isolate were tested, and it was found that none of the samples were significantly different from one another.

Consumer tests of the products revealed that the 750 head size was a better choice than the 1610 or 1614 to produce a maximally acceptable product that does not differ significantly in acceptance from whole muscle meat. Sensory-instrumental correlations suggest that good prediction of the sensory texture of these products can be achieved using a multiple regression approach, and these data, combined with SEM data, showed that tenderization of these meats is primarily attributable to mechanical disruption of the tissue and not to an enzymatic process.

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*See Discussion with Reviewers

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Discussion with Reviewers

Reviewer #1: To draw the conclusion that enzymatic tenderization did not occur by using SEM photographs would have greater acceptance by this reviewer if a comparison to a known sample which had been enzymatically tenderized were shown. In other words, do we know if the changes due to enzymatic activity can be picked up on the SEM?

Authors: Although there have been several papers written on this subject, the one by Robbins et al. (1979) shows chemical, light microscopic and SEM evidence for the action of catheptic enzymes on muscle.

Reviewer #1: The authors' statement concerning the modification of processing variables, e.g., mixing time, to take advantage of tenderization by enzymes is only true from a point of view involving enzymatic activity. However, recommending longer mixing times without the consideration for mixing time effects of texture modification may mislead some readers. Mixing time effect on texture is a dramatic influence.

Authors: What our statement implied was that the modification of processing methods, including mixing time, would take advantage of enzymatic tenderization, thereby improving the textural qualities. Reviewer 1's comment concerning concomitant effects of these modifications is well taken.