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Triticale for Food Uses

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Triticale is a cross between wheat and rye. Triticale grains were dry-milled into flour (61–65%), shorts, and bran. Bran fraction and shorts were high in protein and lysine. The flour was finely reground and air classified. The high-protein fractions accounted for 19–25% of the flour and had about twice the protein content of flour. An alkaline extraction process gives protein concentrate and starch from ground triticale. Protein content of the concentrates varied between 82 and 87% and accounted for 53 to 59% of total triticale protein. All protein concentrates had good hydration capacity (near 4), excellent emulsifying activity (near 90%), and excellent emulsion stability (around 85%). The high-protein fractions from triticale flour could find use as protein supplements, and the protein concentrates may be used in foods as protein ingredients, fat emulsifiers, and water-absorbing agents. Triticale grain and fractions have been extruded into breakfast cereal or snack food.

Triticale, the first man-made cereal, is a cross between wheat and rye. The name triticale is derived from *Triticum* (wheat) and from *Secale* (rye). Plant breeders from many countries are trying to combine the quality and uniformity of wheat with the hardiness, vigor, yield capacity, and disease resistance of rye.

A hexaploid triticale (six sets of chromosomes) results from crossing a durum wheat (four sets of chromosomes) with a rye (two sets of chromosomes). An octoploid triticale (eight sets of chromosomes) results from crossing a bread wheat (six sets of chromosomes) with a rye (two sets of chromosomes). Hexaploid triticales (from durum × rye) are more fertile and more vigorous than octoploid triticales (from bread wheat × rye). One or more sets of the bread wheat chromosomes can be transferred to hexaploid triticales by crossing hexaploid triticale with hexaploid wheat or with octoploid triticales. Nearly all advanced triticale lines are now hexaploid, but most have been crossed at some stage with an octoploid triticale or bread wheat to introduce into hexaploid triticales the best characteristics from bread wheats.

High yielding triticales now have 10.5 to 13.5% protein compared with 10 to 12% protein in bread wheats grown in the same fields at International Maize and Wheat Improvement Center in Mexico (CIMMYT, 1976). The shriveled grains of early triticales had a low starch content and, therefore, an extraordinarily high percentage of protein. In 1975, advanced triticales had 3.2 to 4.2% lysine compared with 2.3 to 3.0% for bread wheat. The percent of lysine, the first limiting amino acid in triticale, generally determines the protein quality. The best triticales can compete in yield with the best wheats today. In general, triticales have outyielded wheat varieties only in areas of the world with soil and climatic conditions not well suited for wheat. Hungary and Spain already have sizable plantings of triticale.

Lorenz et al. (1972b) compared samples of both spring and winter wheats with triticales for mixing and baking properties. They found that breads of very acceptable quality can be produced with certain varieties of triticale, and only minor adjustments are required in absorption and mixing time from those indicated by the mixograph. However, the triticale flours were actually lower in protein content than the wheat flours due to milling difficulties of shriveled triticale kernels. Tsen et al. (1973) studied the farinograph properties and baking performance of three triticale flours of different protein content. They made acceptable bread from triticale flour (13.6% protein) without supplementing with wheat flour by eliminating bulk fermentation and adding 0.5% sodium stearoyl-2 lactylate, 0.25% sucrose tallowate, or 0.25% ethoxylated monoglycerides. These authors found, however, that the low-protein (11.1%) triticale flour required wheat flour supplements to produce acceptable bread, and the triticale bread staled almost twice as rapidly as wheat bread. Müntzing (1966) and Lorenz (1972) also reported the successful production of 100% triticale breads. Triticale flour dough developed much faster with a substantially lower absorption and shorter stability toward mixing than wheat flour dough (Tsen et al., 1973; Unrau and Jenkins, 1964).

The effect of bread volume without any dough conditioners of different levels of triticale flour was studied by Rooney et al. (1969), Unrau and Jenkins (1964), and Vallejo et al. (1969). Rooney et al. (1969) observed that bread volumes decreased gradually with increasing level of triticale flour, but Unrau and Jenkins (1964) and Vallejo et al. (1969) found the bread volumes actually increased and reached a maximum when 20% triticale flour was used. These authors observed that substitution of triticale flour for up to 30 to 40% wheat flour did not markedly decrease loaf volume and internal characteristics of breads.

Cakes prepared from chlorinated triticale flour were superior to those from untreated flour in volume and crumb (Thompson and Vaisey, 1971). However, they found that cake made from chlorinated triticale flour was not as good as that from standard cake flour. Acceptable white layer cake with good symmetry and uniformity was made from triticale flour replaced with more than 40% standard cake flour (Tsen, 1974). Volumes from chlorinated triticale flour were considerably below the level of cake from soft red winter wheat patent flour, but removal of large particles by rebolting on 165-mesh sieve and reduction of particle size by pin-milling improved performance of triticale flours (Kissell and Lorenz, 1976). They observed that with 3% added emulsifier, blends of triticale–wheat flour containing 20 to 50% triticale produced cake volume equal to or larger than soft red winter patent flour without added emulsifiers.

Acceptable sugar cookies can be prepared from triticale flour; however, the spread ratio and top grain of cookies from soft red winter wheat flour are superior to those from triticale flours (Tsen, 1974). Surfactants such as sodium

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Table I. Composition of Triticale and Other Grains (% Dry Basis)[a]

grain	protein	fat	fiber	ash
triticale				
204	17.1	1.7	3.1	2.1
131	13.9	1.9	2.4	2.0
385	13.9	1.5	2.4	2.0
209	14.4	1.7	2.8	
commercial	16.0	2.0	3.4	2.0
wheat[b]				
durum	15.0	2.2	2.5	2.0
hard red spring	16.4	2.1	2.7	2.0
hard red winter	14.6	1.8	3.0	2.0
soft red winter	12.3	1.8	2.5	2.0
rye[b]	13.4	1.8	2.6	2.1

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stearoyl-2 lactylate improve the quality of triticale cookies as measured by the increase in spread ratio, but baking quality varies with different triticales and this ratio is independent of protein content (Tsen, 1974). He observed that other cookies, pancakes, doughnuts, and muffins can also be successfully prepared from triticale flour.

When triticale flour was compared with durum flour, semolina, and all-purpose flour for the manufacture of noodles, regular triticale noodles had the shortest cooking time and the greatest cooking tolerance (Lorenz et al., 1972a). No flavor differences were noted in regular and egg noodles from various flours, but both regular and egg triticale noodles showed considerably higher cooked weights. Lorenz et al. (1972a) found that egg noodles greatly reduce cooking loss and concluded that triticale can be used for the manufacture of noodles.

Malts from certain triticale lines are higher than barley malt in total extract, enzymatic activities, and protein solubilities (Pomeranz, 1974). Some of the triticale beers had excellent gas stability and clarity-stability indices, together with acceptable taste (Pomeranz et al., 1970). Triticale malts may be used as enzymatic supplements for brewing, distilling, and breadmaking (Pomeranz, 1974).

A protein concentrate was made by wet processing bran at different pH values from 6 to 10 (Saunders et al., 1974). The yield of protein concentrate from bran was 8 to 21%, and the protein content (nitrogen × 6.25) of the concentrate was 61 to 43%. If starch was removed during wet processing at pH 8.6, the concentrate had a protein content of 72 to 74% but a considerably lower yield (6 to 7%). After defatting the concentrate with chloroform–methanol (2:1), a product with 88% protein at 5% yield was obtained. One protein concentrate had a PER of 1.8.

This review will emphasize work carried out at the Northern Regional Research Center in dry milling, air classification, wet milling, extrusion cooking, and preparation of protein concentrate (Anderson et al., 1974; Stringfellow et al., 1976; Wu et al., 1976). Lorenz (1974) reviewed the history, development, and utilization of triticale including food applications, and Hulse and Laing (1974) reported the nutritive value of triticale protein.

DRY MILLING

The compositions of five triticale varieties are compared with those of wheat and rye in Table I. Protein content (N × 5.7) of the triticales ranged from 13.9 to 17.1% and did not differ greatly from that of wheat and rye. Fat, fiber, and ash values of the triticales were, in general, similar to those of wheat and rye. Among the five triticales, 204 and the commercial blend had higher protein and fiber contents than the other three. Triticales 131 and 385 are winter hexaploids grown in Kansas and are less wrinkled than 204, a spring hexaploid grown in Texas.

Table II. Flour Yield and Composition of Triticale Milled on a Buhler Mill (14% Moisture Basis)[a]

triticale	yield, %	protein, %	ash, %
204	63.8	12.1	0.53
131	61.9	10.2	0.52
385	65.0	10.4	0.52
209	62.4	11.1	0.45
commercial (Texas)	60.7	12.0	0.48

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Table III. By-Product Yield and Composition of Triticale Milled on a Buhler Mill (14% Moisture Basis)[a]

	shorts			bran		
triticale	yield, %	protein, %	ash, %	yield, %	protein, %	ash, %
204	9.9	16.5	2.5	26.3	19.7	4.9
131	12.4	14.6	2.5	25.7	16.2	4.8
385	13.5	14.9	2.5	21.5	17.3	4.4
209	9.3			28.3		
commercial (Texas)	8.9	15.7		30.4	17.1	

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Table IV. Essential Amino Acid Composition of Triticale Grain and Buhler-Milled Fractions (g/16 g of N)[a]

	grain		bran		shorts		flour	
amino acid	204	385	204	385	204	385	204	385
lysine	3.4	3.4	4.4	4.4	3.6	3.7	2.5	2.4
threonine	2.9	3.1	3.5	3.0	3.2	3.2	2.8	2.9
valine	4.5	4.6	4.8	4.6	4.7	4.9	4.4	4.4
methionine + cystine	2.8	2.9	2.7	2.4	3.0	3.0	2.8	3.7
isoleucine	3.5	3.5	3.3	3.5	3.4	3.6	3.5	3.5
leucine	6.9	6.2	6.2	6.3	6.2	6.3	7.0	6.4
phenylalanine + tyrosine	7.6	7.9	7.6	7.7	7.4	7.7	7.9	8.7

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The triticale grain of 12.5% moisture content was tempered overnight to 14.5% moisture and then raised to 15.5% 30 min before milling in a Buhler pneumatic laboratory mill, type MLV-202. The yield of flour varied from 61 to 65% (Table II) for the five triticale grains. Protein contents of 204 and commercial flours are higher than those of 131, 385, and 209, and this level reflected initially higher protein contents of the first two grains. There was a clean separation of bran and shorts from the flour. Kaltsikes and Larter (1970) reported flour yield of 54 to 58% with Buhler mill, and Lorenz (1972), Madl and Tsen (1973), and Rooeny et al. (1969) obtained 56–62, 58–64, and 51–63% of flour, respectively, from Quadrumat Senior mill. The yield of flour from triticale was lower than that usually obtained from hard and soft wheats. Ash content of triticale flours (except 209) appeared slightly higher than those of hard wheat flours from Buhler mill.

The by-products of milling, bran and shorts, were recovered in higher yield than usually obtained from wheat (Table III). Protein levels of the bran and shorts ranged froom 15 to 20% and exceeded those of the flours. Among

Table V. Yield and Composition of Fractions Produced by Fine Grinding and Air Classification of Triticale Flours (14% Moisture Basis)[a]

kind of flour and fraction no.	yield, %	protein, %	ash, %	fat, %
204				
flour	100.0	12.7	0.57	0.69
fraction 1	10.7	34.3	1.2	1.6
fraction 2	8.0	28.4	0.9	1.1
fraction 3	6.4	20.7	0.7	0.9
fraction 4	22.8	6.7	0.5	0.4
fraction 5	14.0	4.8	0.5	0.3
fraction 6	16.8	4.4	0.4	0.3
fraction 7	11.7	5.6	0.5	0.3
fraction 8 (coarse residue)	9.6	13.3	0.5	0.4
385				
flour	100.0	10.4	0.58	0.5
fraction 1	7.1	30.2	1.7	1.6
fraction 2	6.0	24.3	1.2	1.2
fraction 3	5.4	17.4	0.8	1.0
fraction 4	21.2	6.5	0.4	0.5
fraction 5	13.6	5.2	0.3	0.4
fraction 6	16.8	5.1	0.3	0.4
fraction 7	12.6	6.8	0.3	0.4
fraction 8 (coarse residue)	17.3	12.4	0.4	0.5

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the five triticales, 204 gave the highest protein content for flour and by-product fractions. The difference in protein content of the whole grains (Table I) and flours (Table II) was about two percentage units when expressed on the same moisture basis. This difference is about twice that usually found for hard wheats of similar protein contents.

Content of lysine and other essential amino acids for 204 and 385 (Table IV) varieties was similar for both whole grains. The lysine level in the triticale grain protein was 10–25% higher than that for wheat grains of different types (Kasarda et al., 1971). However, triticale 385 grown in the high-altitude regions of the United States did not have higher lysine values in comparison with wheat varieties grown under the same agronomic and climatic conditions (Lorenz et al., 1975). Bran had the highest lysine level and flour the lowest among grain, bran, shorts, and flour. Shorts had similar amino acid composition when compared with bran, but the latter was higher in lysine. Triticale flour had considerably lower lysine than whole grain, and this difference was more than that of wheat (Kasarda et al., 1971). Flour was composed of three break flours and three reduction flours. The separate use of any break or reduction flour of triticale offers no significant economic or nutritional advantages on the basis of yields, protein levels, and amino acid contents (not shown in table). Since both bran and shorts contained high protein levels and good amounts of essential amino acids, those fractions may be nutritionally beneficial in foods.

AIR CLASSIFICATION

The flour was further ground by passing it three times through an Alpine Kolloplex pin mill (Model 160-Z) operating at 14000 rpm. Air classification of this finely ground flour was carried out in a Pillsbury laboratory model air classifier. The flours were separated into eight fractions by collecting a fine fraction, readjusting the classifier for a coarser cut, reclassifying the coarse fraction, and repeating the procedure until seven fine fractions and one coarse fraction remained. Classifier cut points were set to yield fractions with particle sizes (reported in terms of mass median diameter, the diameter at which 50% of weight of sample is undersize) of about 11, 12, 15, 18, 21, 23, and 25 μm. Separations are near maximum for this technique because of the large number of fractions taken and the intensive flour regrinding imposed (Gracza, 1959).

Air classification results for finely ground triticale flours are given in Table V. The pattern is similar to those of wheat flours, namely, fractions with particle size below 15 μm (fractions 1–3) had much higher protein contents than those of the original flour. The highest protein content was in fraction 1 of 204 flour (34.3%). The finer fractions also contained higher fat and ash contents, which appeared to parallel the higher protein contents. The starchy or low-protein fractions 4 through 7 varied in yield from 12 to 23% and in protein content from 4.4 to 6.8%. Coarse residues from the two varieties are different in terms of the relation of protein level to that of the parent flour, and are similar to that found for wheats of different hardness classes. The more vitreous varieties (hard red spring wheats and triticale 385) showed higher protein in coarse residue than in the starting flour, whereas the less hard classes for both grains (hard red winter wheat and triticale 204) did not have significantly higher protein level in the coarse residue as compared to starting flour (Peplinski et al., 1965; Stringfellow and Peplinski, 1964). However, triticale 385 grown in the high-altitude regions of the United States is not considered a vitreous variety.

Fractionation results obtained from air classifying the three triticale flours are compared to those of a rye and

Table VI. Comparison of Fractionation Responses of Reground Flours from Triticale, Rye, and Wheat (Expressed as % on 14% Moisture Basis)[a]

	triticale			rye,[b] commercial mix	wheat		
sample	204	131	385		hard red spring selkirk[c]	hard red winter wichita[d]	soft red winter vermillion[e]
flour, protein	12.7	10.2	10.4	10.9	12.3	10.9	9.4
maximum range of protein	34.3-4.4	27.6-4.7	30.2-5.1	21.5-6.2	23.7-7.6	29.4-5.5	26.7-2.3
combined high-protein fractions 1-3							
yield	25.1	21.7	18.5	25.8	18.8	21.0	29.4
protein	29.0	22.1	24.5	19.8	19.4	24.4	21.4
combined starchy fractions 4-7							
yield	65.3	64.6	64.2	56.8	49.5	52.9	64.5
protein	5.5	5.6	5.9	7.4	8.7	6.5	3.3
coarse residue fraction 8							
yield	9.6	13.7	17.3	17.4	31.7	26.1	6.1
protein	13.3	12.8	12.4	9.6	14.2	9.8	6.2
protein shifted, total	73	58	56	41	29	50	82

[a] Reprinted with permission from Stringfellow et al. (1976). Copyright 1976 American Association of Cereal Chemists. [b] Anderson et al. (1972). [c] Peplinski et al. (1965). [d] Stringfellow and Peplinski (1964). [e] Peplinski et al. (1964).

Table VII. Some Essential Amino Acids in Air-Classified Fractions of Triticale 385 Flour[a]

protein content[b] or amino acid	g of amino acid/16 g of nitrogen								
	parent flour	fractions							
		1	2	3	4	5	6	7	8
protein content	10.4	30.2	24.3	17.4	6.5	5.2	5.1	6.8	12.4
lysine	2.5	2.7	2.5	2.4	2.6	2.9	2.7	2.7	2.5
threonine	2.9	3.0	3.0	2.9	3.1	3.0	2.9	2.9	3.0
valine	4.6	4.8	4.5	4.5	4.6	4.6	4.7	4.7	4.7
methionine	2.0	1.8	1.9	1.8	2.0	1.9	1.8	1.8	1.7
isoleucine	3.7	3.7	3.6	3.7	3.9	3.8	3.9	3.9	4.0
leucine	6.5	6.8	6.6	6.6	6.6	6.8	6.7	6.9	7.0
phenylalanine	5.4	5.4	5.5	5.4	5.4	5.4	5.3	5.7	5.7

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two different types of wheat (Table VI). Although hard red spring wheat, hard red winter wheat, soft red winter wheat, triticales, and rye were grown in different parts of the United States, comparison of fractionation result is still useful. Maximum range of protein content among the eight classified fractions was from 204, 4.4 to 34.3%. Protein shift is a calculated value for comparing protein displacement and equals the sum of the protein shifted into the high-protein fractions and out of the low-protein fractions, expressed as percentage of the total protein present in the flour (Gracza, 1959). The greater ease of fractionation is also reflected in the highly significant protein shift of 73% in 204 flour as compared to 56 to 58% from 131 and 385 flours, 41% for rye flour, and 29 to 50% for the two hard wheats. Triticale 204 behaved much like the soft wheat, which had a high protein shift (82%).

Triticale 204 gave a 25% yield of the three high-protein fractions (Table VI), equal to that of rye flour (26%), less than that of soft wheat flour (29%), and more than that of hard wheat flours (19–21%). Protein content of the combined high-protein fractions (29%) from 204 was considerably more than from the rye fraction (20%) or the hard and soft wheat fractions (19–24%). Yields and protein contents of the three high-protein fractions from 131 and 385 flours were similar to the hard wheat flours.

The essential amino acid composition of fractions from 385 flour showed no major variation (Table VII). Air classification does not selectively concentrate specific protein classes in different fractions. Concentration of protein into the finer fractions maintains the nutritional quality of the triticale flour protein in those fractions. The better nutritional quality of triticale high-protein fractions compared to high-protein wheat fractions (2.3 vs. 1.6 to 1.9 g of lysine/16 g of nitrogen) suggests use of such fractions in breakfast cereals, snack foods, and pancake flours where improvement in protein level and quality is desirable.

EXTRUSION COOKING

Commercial blend of triticale grain was milled to yield several different types of products, and then extrusion cooked in a laboratory Wenger X-5 machine according to the procedures described by Conway and Anderson (1973). Table VIII lists the products tested and some of the properties of the final cooked products, which varied in color depending on the amount of hull or bran present in the fraction. Expansion (expressed as diameter of product divided by diameter of the die) occurred in all the products, the degree depending on the dilution of the starch by protein and bran. The products were seasoned and informally judged by several groups. All were found acceptable except the cooked shorts, which expanded little.

Food blends of the instant corn–soy–milk (CSM) type based on triticale have been prepared. Whole ground triticale was extrusion cooked, ground, and blended with proper proportions of soy flour, vitamins, minerals, sugar, and flavoring to give an instant product containing 21% protein that can readily be mixed with water to yield a gruel or a beverage. Lorenz et al. (1974) also found that a very acceptable breakfast cereal could be produced by extrusion processing of tempered whole-grain triticale.

Table VIII. Direct Extrusion Cooking of Milled Triticale Products[a]

milled product	protein, % dry basis	fat, % dry basis	available lysine, g/16 g of N	expansion
cracked whole grain (CWG)	16.5	1.2	3.3	2.5
85% CWG and 15% defatted soy flour	21.9	1.0	3.6	2
partially dehulled CWG (12% removed)	15.4	1.0	2.3	3
85% partially dehulled CWG and 15% defatted soy flour	21.0	1.0	3.4	2.5
shorts from regular flour milling	16.6	2.1	3.3	1.5

[a] Reprinted with permission from Anderson et al. (1974). Copyright 1974 Institute of Food Technologists. Commercial blend of triticale used.

Table IX. Yield and Composition of Wet-Milled Fractions from Various Flours (% dry basis)[a]

item	triticale 204	soft winter wheat	hard red spring wheat
flour protein	14.7		16.4
gluten yield from flour	17.0	14.0	17.8
protein in gluten	70	80	78
flour protein recovered in gluten	81	80	84
lysine in gluten protein	2.3	1.9	1.6
starch yield	69	71	70
protein in starch	0.4	0.4	0.3

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WET MILLING OF FLOUR

Wet-milling experiments with 204 flour in Table IX are compared with earlier reported yields of products from flours of a soft white winter wheat and a hard red spring wheat (Knight, 1965). A Martin type process on a laboratory scale was used, and the flour was kneaded to yield a dough ball, which was washed to remove the starch. The dough could only be worked with care, because triticale yielded a soft, weak gluten ball. However, the recovery of protein in the gluten was comparable to that from wheat

Table X. Essential Amino Acids of Triticale 204 Grain, Flour, and Gluten Extracted from Flour (g of amino acid/16 g of nitrogen)[a]

amino acid	whole grain	flour	gluten
lysine	3.3	2.5	2.3
threonine	2.9	2.8	2.7
valine	4.8	4.4	4.0
methionine + cystine	2.3	2.8	3.1
isoleucine	3.6	3.5	3.4
leucine	7.3	6.9	6.1
phenylalanine + tyrosine	7.4	7.9	10.3

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flours. Solids present in the process water were 10% of the flour. These soluble solids contained 26% protein on dry basis and have potential as a nutrient in foods, fermentation media, or source of water-soluble proteins.

Essential amino acids of 204 gluten, its parent flour, and grain are listed in Table X. Lysine, valine, and leucine in the gluten were somewhat lower than those of the flour, but there was an increase in the sulfur amino acids, cystine plus methionine, and in tyrosine plus phenylalanine.

The rather high yield, 69%, of high-quality starch (Table IX) is encouraging for triticale 204 flour. The starch has a protein content of 0.4%, which is essentially the same as starch from wheat or corn. Viscosity properties of triticale 204 starch are also favorable (Table XI) and are compared to those of wheat and corn. Triticale 204 starch had a little lower pasting temperature than corn or wheat, but other viscosity characteristics of this triticale starch were between those of wheat and corn. It seems that triticale starch could be used in similar manner to that of corn starch from the standpoint of viscosity. Other workers have reported that triticale starch possesses chemical and physical properties somewhat like those of its parents (Berry et al., 1971; Klassen and Hill, 1971).

WET MILLING OF GRAIN

Triticale 204 grain was wet milled in the laboratory by an experimental milling procedure previously described (Anderson, 1963). Grain was steeped in distilled water containing 0.3% sulfur dioxide for 24 h at 100 °F, and the steeped grain was then processed by milling, screening, and tabling. Steeped grain was soft and ground quite easily. Coarse and fine fiber fractions, which included the germ, were washed almost free of starch with little difficulty. They contained less than 12% starch after routing washing. Starch–gluten separation was typical of that of wheat in wet milling (Table XII). Yield of starch from triticale was 41%, about the same as that of starch from wet milling hard wheats but less than that from soft wheat. Triticale starch recovery (based on starch in grain and ease of starch–gluten separation) was in the range of that from wheat milling but considerably less than that from corn milling. Purity of starch with respect to protein, 0.27%, was excellent. Gluten recovered in this process has reduced

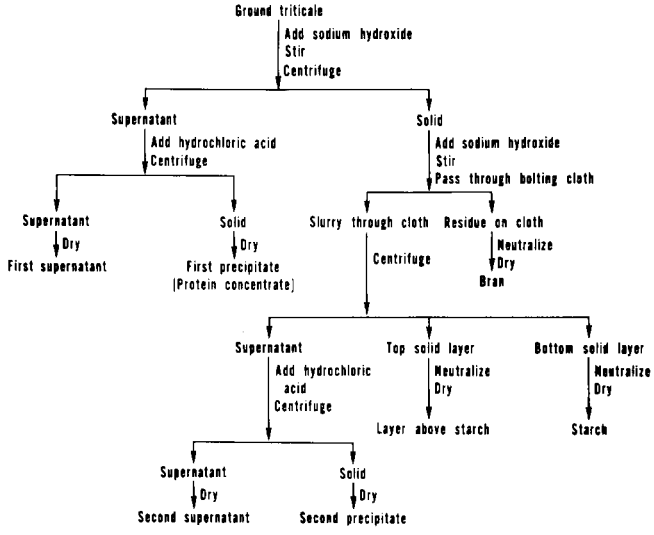

Figure 1. Schematic diagram for preparing protein concentrate and by-products from ground triticale (Wu et al., 1976).

elasticity due to modified sulfide bonds from sulfur dioxide steeping.

PROTEIN CONCENTRATE BY ALKALINE EXTRACTION OF GRAIN

Solvent. A number of solvents were used to extract triticale 204 protein from ground grain at a solid-to-solvent ratio of 1:6 (Table XIII). The grain was ground twice in a hammer mill. Ground grain and solvent were stirred for 25 min and centrifuged for 10 min at 3300*g*. A portion of the supernatant from centrifugation was analyzed for nitrogen. The protein content in extracted solids (freeze-dried supernatant) reached a maximum of 67% at pH 10.9 where 79% of the triticale protein was extracted. At higher pH values the percentage of triticale protein extracted increased slightly, but there was more risk of modifying the triticale protein and more chance of starch gelatinization.

Ground triticale 204 was extracted with sodium hydroxide solutions at solid-to-solvent ratio of 1:3 to 1:10 (Table XIV). Since the percentage of protein extracted by sodium hydroxide solutions depends on pH of the slurry (Table XIII), normality of the sodium hydroxide was adjusted to give the same slurry pH of 10.9. A solid-to-solvent ratio of 1:6 is probably a good compromise between the highest percentage of protein extracted and a minimum amount of extractant needed (Table XIV).

The effect of precipitation pH on the alkaline extract of triticale 204 was determined at six pH values from 4 to 6.5. The amount of protein precipitated ranged from 45 to 72% (Table XV) and this large difference demonstrated the importance of correct pH value for precipitating triticale protein from the alkaline extract. The maximum amount of protein precipitated, 72% at pH 4.5, was essentially maintained between pH 5.0 and 5.5.

Preparation of Protein Concentrate and By-Products. Ground triticale (150 g) and 900 mL of 0.05

Table XI. Amylograph Viscosity Patterns for Triticale 204 Starch and Other Starches[a]

starch	pasting temperature, °C	peak viscosity, B.U.[b]	viscosity at 95 °C, B.U.	viscosity after hold, 95 °C, 1 h, B.U.	cold paste viscosity, 50 °C, B.U.
triticale 204	63	790	780	650	1230
wheat	64	740	670	570	1000
corn	68	1090	960	750	1470

[a] Reprinted with permission from Anderson et al. (1974). Copyright 1974 Institute of Food Technologists. [b] B.U. = Brabender unit.

Table XII. Comparison of Starch Recovery and Analysis from Conventional Wet Milling of Triticale and Other Grains (% dry basis)[a]

starch	triticale 204	hard red spring wheat[b]	soft white winter wheat[b]	corn[c]
in whole grain	58.2	60.3	67.4	73.8
processing data				
yield[d]	41.2	38.9	50.5	65.4
recovery[e]	70.6	64.5	73.2	87.9
protein	0.27	0.27	0.24	0.5

[a] Reprinted with permission from Anderson et al. (1974). Copyright 1974 Institute of Food Technologists. [b] Data from Slotter and Langford (1944). [c] Data from Anderson (1963). [d] Based on grain. [e] Based on starch present in grain.

Table XIII. Extraction of Triticale 204 Protein[a] with Various Solvents[b]

solvent	pH of slurry	triticale protein extracted, %	protein in extracted solids, %
water	6.2	18	32
hydrochloric acid[c]	3.5	20	34
0.1 N acetic acid	4.4	25	35
1 N acetic acid	3.4	34	46
0.03 N sodium hydroxide	9.9	53	57
0.04 N sodium hydroxide	10.5	69	63
0.05 N sodium hydroxide	10.9	79	67
0.08 N sodium hydroxide	11.6	81	63

[a] Solid-to-solvent ratio, 1:6, dry basis. [b] Wu et al. (1976). [c] Hydrochloric acid (1 N) was added dropwise to the slurry until pH 3.5; exact normality not known.

Table XIV. Effect of Solid-to-Solvent Ratio on Extraction of Triticale Protein[a,b]

solid:solvent ratio	solvent (sodium hydroxide), N	protein extracted, %
1:3	0.1	47
1:4	0.075	58
1:6	0.05	75
1:10	0.03	82

[a] Triticale 204; slurry pH 10.9. [b] Wu et al. (1976).

Table XV. Effect of Precipitation pH of Alkaline Extract on Protein Recovery[a]

pH	% protein precipitated from alkaline extract
4.0	64
4.5	72
5.0	71
5.5	71
6.0	64
6.5	45

[a] Wu et al. (1976).

N sodium hydroxide were stirred 25 min, and the slurry was adjusted to pH 10.8 (Figure 1). The slurry was centrifuged at 3300g for 15 min, and the supernatant was adjusted to pH 4.6 to precipitate the protein. The mixture was centrifuged to yield a precipitate and a supernatant,

Table XVI. Products from Alkaline Processing of Triticales 204 and 385[a,b]

	yield, %			% of total triticale protein[c]		
	204		385	204		385,
product	pH 10	pH 10.8	pH 10.8	pH 10	pH 10.8	pH 10.8
protein concentrate (first precipitate)	9	11	11	42	53	59
first supernatant	9	9	9	15	18	17
second precipitate	2	2	1	8	6	4
second supernatant	3	2	2	9	5	3
bran	25	22	28	15	10	13
layer above starch	9	12	17	4	4	2
starch	42	38	29	0	1	0
total	99	96	97	93	97	98

[a] Solid-to-solvent ratio was 1:6, dry basis. [b] Wu et al. (1976). [c] Nitrogen x 5.7.

which were freeze-dried separately as the first precipitate (protein concentrate) and first supernatant. The alkaline residue from the first centrifugation was redispersed to original volume and pH. This slurry was stirred and passed through 100-mesh bolting cloth to remove bran. Slurry that passed through the cloth was centrifuged to give a supernatant, a starch layer, and a layer above starch. The supernatant was adjusted to pH 4.6, centrifuged, and freeze-dried to give second precipitate and second supernatant. For extraction at pH 10.0, 0.04 N sodium hydroxide was used instead of 0.05 N.

The yield of protein concentrate increased from 9 to 11% (Table XVI) when the pH was raised from 10 to 10.8 for triticale 204; also, the total protein accounted for by the concentrate increased from 42 to 53%. The yields of first supernatants, second precipitates, and second supernatants were about the same at pH 10 and 10.8, but the yield of bran was lower at the higher pH.

Both protein content and variety affect extraction at pH 10.8 (Table XVI). Although the yield of protein concentrate was the same for triticales 204 and 385, the percentage of total protein accounted for by the concentrate was lower for 204 compared with 385. Yields of the first supernatants, the second precipitates, and the second supernatants were about the same for both varieties, but yields of the 204 bran and layer above starch were considerably lower than that from 385. The yield of starch for 204 is the same as that from conventional wet milling of triticale and of hard red spring wheat (Table XII). A much higher yield of starch was observed for 204 compared with 385. The lower yield of bran and higher yield of starch for 204 compared with 385 indicate that 204 responds better than 385 to alkaline wet processing.

Composition. The proximate analyses and starch contents of protein concentrate and by-products extracted at pH 10 and 10.8 from triticales 204 and 385 appear in Table XVII. Fiber and ash were determined according to AACC Approved Methods (1971), and starch was determined by a polarimetric method (Garcia and Wolf, 1972). In addition to protein, fat, fiber, ash, and starch, triticale also contains pentosans (Heinrichs and Hill, 1971) and sugars (Vaisey and Unrau, 1964). For triticale 204 extracted at pH 10.8, the concentrate had a protein content of 87%, low fiber (0.1%), ash (1.5%), and fat [3.1%, ether extraction (EE)]. The second precipitate had lower protein and ash but higher fat than the protein concentrate. The first and second supernatants had from 35 to 44% protein, low levels of fat and fiber, but high ash. The layer above starch consists mainly of starch and had lower protein, fat, and fiber but higher ash and starch than bran. The starch

Table XVII. Composition of Protein Concentrate and By-Products from Triticales 204 and 385 (% Dry Basis)[a]

material	protein (N × 5.7)			fat					fiber		ash			starch		
	204		385,	204			385		204	385	204		385,	204		385,
				EE		GLC,	EE	GLC								
	pH 10	10.8	10.8	10	10.8	10.8	10.8		10.8		10	10.8	10.8	10	10.8	10.8
ground triticale	17.7	17.7	15.0	1.7	1.7	1.7	1.3	2.0	2.8	2.6	2.1	2.1	1.8	56.5	56.5	60.5
protein concentrate (first precipitate)	80.0	86.5	82.3	2.0	3.1	6.7	1.7	8.4	0.1	0.1	2.2	1.5	2.1			
first supernatant	31.3	34.7	28.4	0.2	0.3	0.2	0.1	0.1	0.2	0	15.3	17.3	22.3			
second precipitate	79.7	68.0	69.3	8.2	24.5	23.3	12.5	17.3			1.0	1.0	1.5			
second supernatant	58.1	44.2	29.1	0.2	0.1		0.1				9.1	24.4	20.1			
bran	10.6	8.1	7.1	1.1	1.4	1.7	0.5	1.3	11.2	8.4	3.4	3.3	2.9	36.8	38.2	46.0
layer above starch	9.0	5.9	1.8	0.4	0.9	0.7	0.1	0.3	2.7	1.6	4.2	4.4	1.8	72.0	67.3	88.2
starch	0.2	0.2	0.2	0	0	0.1	0	0.1	0.1	0.1	1.1	0.5	1.4	101	93.3	92.3

[a] Wu et al. (1976). Key to abbreviations: EE, petroleum ether extraction; GLC, gas–liquid chromatography.

fraction had low protein (0.2%), no fat, low fiber, and is consistent with a high-quality material.

At pH 10, extraction of 204 concentrate was less efficient in terms of protein content (80 vs. 87%) and yield (9 vs. 11 in Table XVI). The starch fraction was equally low in protein (0.2%) at both pH values; however, proximate compositions and starch content of protein concentrate and by-products follow the same trend at pH 10 as at pH 10.8. The lower protein, fat (EE), and fiber but higher starch contents of 385 grain compared with 204 are, in general, reflected in lower protein, fat, and fiber and higher starch for all 385 fractions compared with equivalent 204 fractions. Ash contents of protein concentrate, first supernatant, second precipitate, and starch from 385 were higher than those from 204, but the trend was reversed for second supernatant, bran, and layer above starch. The gas–liquid chromatograpy (GLC) procedure (Black et al., 1967) for fat determination measured total fat and, therefore, gave higher fat value than that from EE in general.

Neutral Carbohydrates. The amount and kinds of neutral carbohydrates from acid hydrolysates of protein concentrate and by-products from triticales 204 and 385 are listed in Table XVIII. The neutral carbohydrates are determined by a GLC procedure on acid-hydrolyzed samples (Sloneker, 1971). For ground triticale 385 the hydrolysate contained small amounts of arabinose and xylose, in addition to a large amount of glucose. Arabinose and xylose are derived from pentosans (Heinrichs and Hill, 1971) and hemicellulose (Vaisey and Unrau, 1964). Most of the glucose is derived from starch because 385 grain has 61% starch (Table XVII). The rest of the glucose is mostly from such oligosaccharides as maltotriose, maltotetraose, and maltopentaose (Vaisey and Unrau, 1964), although smaller amounts of glucose, sucrose, and maltose also contribute (Vaisey and Unrau, 1964).

The 385 concentrate yielded no neutral sugar on acid hydrolysis, and the second precipitate produced 4% glucose. Arabinose and xylose from acid hydrolysates of first and second supernatants of 385 are probably derived from water-soluble pentosans, whereas glucose from the hydrolysates of first and second supernatants came mostly from maltotriose, maltotetraose, and maltopentaose with some contribution from glucose, sucrose, and maltose. The second supernatant and bran from 385 produced a small amount of galactose, which was not detected in the starting triticale because of differences in concentration; the yields of the second supernatant and bran were only 2 and 28%, respectively (Table XVI). Among all the fractions, bran yielded the highest amount of arabinose and xylose, which were probably derived mostly from water-insoluble pentosans. The 385 bran had 46% starch (Table XVII) which, after hydrolysis, produced most of the glucose for that fraction in Table XVIII. The layer above starch yielded mostly glucose, derived mainly from starch (88%, Table XVII), and the small amounts of arabinose and xylose were probably produced from water-insoluble pentosans. The starch fraction yielded glucose exclusively. The neutral carbohydrates from acid hydrolysates of 204 and its fraction were similar to the corresponding ones in 385 in general.

Amino Acid Composition. The essential amino acid compositions of protein concentrate and by-products from triticales 204 and 385 were corrected to 100% nitrogen recovery and expressed in grams of amino acid/16 g of nitrogen (Table XIX). Samples for amino acid analyses were hydrolyzed for 24 h by refluxing in 6 N hydrochloric acid, and a portion of each hydrolysate solution was analyzed in a Beckman Spinco Model 121 amino acid ana-

Table XVIII. Neutral Carbohydrates from Acid Hydrolysates of Protein Concentrate and By-Products from Triticales 204 and 385[a-c]

Material	L-arabinose		D-xylose		D-galactose		D-glucose	
	204	385	204	385	204	385	204	385
ground triticale	0	2.5	3.4	3.7	0	0	80.3	72.5
protein concentrate (first precipitate)	0	0	0	0	0	0	1.5	0
first supernatant	2.6	3.0	2.7	3.6	1.6	0	17.3	10.5
second precipitate	0	0	0	0	0	0	3.7	4.1
second supernatant	1.3	3.8	1.8	4.7	0	1.1	9.1	8.9
bran	11.1	7.4	16.4	11.7	0	0.8	57.7	58.3
layer above starch	0	1.3	2.7	1.0	0	0	81.6	91.5
starch	0	0	0	0	0	0	105	107

[a] Extraction pH was 10.8 for triticale 385; 10 for triticale 204. The neutral carbohydrates are expressed as percent of material on extreme left for each horizontal line, dry basis. [b] D-Mannose not detected in any fraction. [c] Wu et al. (1976).

Table XIX. Essential Amino Acid Composition of Protein Concentrate and By-Products from Triticales 204 and 385[a,b]

amino acid	ground triticale		protein concentrate (first precipitate) pH 10,	protein concentrate (first precipitate) pH 10.8		first supernatant		second precipitate		second supernatant		bran	
	204	385	204	204	385	204	385	204	385	204	385	204	385
lysine	3.2	3.4	2.9	3.3	3.2	2.6	3.0	2.3	3.4	1.7	2.0	3.7	4.3
threonine	3.1	3.1	3.5	3.1	3.1	3.3	3.1	3.0	3.1	2.7	2.6	3.8	3.7
valine	4.7	5.0	5.3	4.8	4.8	4.4	4.3	4.8	4.8	4.3	3.9	5.5	5.5
methionine + cystine	3.5	3.5	2.4	3.5	3.8	4.1	5.1	2.5	3.6	3.0	3.9	2.8	3.3
isoleucine	3.7	3.9	3.8	3.8	4.0	3.4	3.2	4.0	4.0	3.8	3.6	3.8	3.9
leucine	6.7	6.4	7.1	6.9	6.8	6.0	5.3	7.3	7.1	6.5	5.8	7.1	7.0
phenylalanine + tyrosine	7.9	8.2	9.2	9.2	9.0	6.0	6.5	8.2	8.5	7.5	7.2	7.1	8.3

[a] Amino acid expressed in g of amino acid/16 g of nitrogen recovered. Extraction pH was 10.8 unless otherwise specified. [b] Wu et al. (1976).

lyzer. Only significant differences in amino acid composition are discussed. The two triticale grains have similar amino acid compositions, but the lysine content of the triticales was considerably higher than that of hard wheat (Horn et al., 1958).

Protein concentrate extracted at pH 10 from triticale 204 had an amino acid composition similar to 204 grain except that the concentrate had higher threonine, valine, phenylalanine plus tyrosine but lower methionine plus cystine than the grain (Table XIX). The 204 protein concentrate extracted at pH 10.8 had higher lysine and methionine plus cystine but lower threonine than that extracted at pH 10. Lysine and methionine plus cystine of the 204 concentrate extracted at pH 10.8 were essentially equal to those of the 204 grain. The lysine content of 3.3 g/16 g of nitrogen for 204 concentrate extracted at pH 10.8 was much higher than the lysine content of 2.3 for gluten prepared from 204 flour by wet milling (Table IX).

The first supernatant from 204 had lower lysine, isoleucine, leucine, and phenylalanine plus tyrosine but higher methionine plus cystine than 204 concentrate extracted at pH 10.8 (Table XIX). The second 204 precipitate had lower lysine, methionine plus cystine, and phenylalanine plus tyrosine than the 204 concentrate extracted at pH 10.8. The second 204 supernatant had lower lysine, threonine, valine, methionine plus cystine, and phenylalanine plus tyrosine than the 204 concentrate extracted at pH 10.8. The 204 bran had higher lysine, threonine, and valine but lower methionine plus cystine and phenylalanine plus tyrosine than the 204 concentrate extracted at pH 10.8.

The amino acid composition of the protein concentrate and by-products from triticale 385 did not differ very much from the corresponding 204 fractions (Table XIX). The first supernatant from 385 had higher lysine and methionine plus cystine but lower leucine than that from 204. The second 385 precipitate had higher lysine and methionine plus cystine than that from 204, and the second supernatant from 385 had higher lysine and methionine plus cystine but lower leucine than that from 204. The 385 bran had higher lysine, methionine plus cystine, and phenylalanine plus tyrosine than 204 bran.

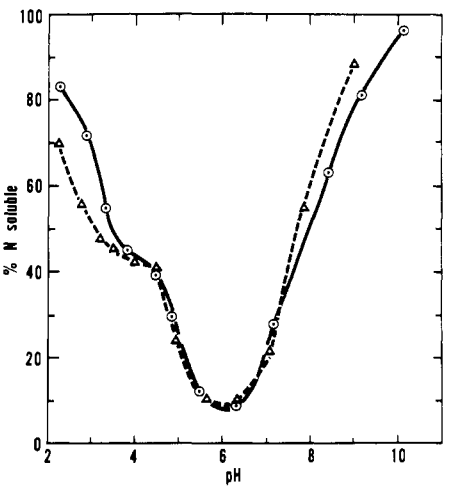

Figure 2. Nitrogen solubility of triticale protein concentrate at various pH values. Protein concentrate (0.1 g) was stirred with 10 mL of water to which either hydrochloric acid (below pH 4) or sodium hydroxide (above pH 4.5) solution was added to arrive at the desired pH: (⊙) 204, (△) 385. Both concentrates were extracted at pH 10.8 (Wu et al., 1976).

Nitrogen Solubility. The triticale protein concentrate used for nitrogen solubility studies was extracted at pH 10.8, and the percentage of nitrogen soluble at a number of pH values from 2.2 to 10.2 for triticale 204 and 385 concentrate is plotted in Figure 2. Nitrogen solubility was determined by mixing 0.1 g of protein concentrate with 10 mL of water, and either sodium hydroxide or hydrochloric acid solution was added dropwise to give a range

Table XX. Some Functional Properties of Triticale Protein Concentrate Compared with a Soy Protein[a]

protein concentrate	protein content, %	extraction, pH	hydration capacity	emulsifying activity, %	emulsion, stability, %
triticale 204	80.0	10	4.1	91	87
triticale 204	86.5	10.8	3.7	85	81
triticale 385	82.3	10.8	3.9	90	85
soy protein isolate				45	45

[a] Wu et al. (1976).

of pH values from 2.2 to 10.2. The mixture was stirred 25 min and centrifuged at 1300*g* (or up to 27 000*g*, if needed) for 20 min to separate solid and supernatant satisfactorily. The supernatant was analyzed for nitrogen, and the percentage of nitrogen soluble was calculated at each pH level.

The minimum solubility of 204 concentrate was near pH 6 (Figure 2), where about 8% of the nitrogen was soluble. The difference in ionic strength accounts for the different pH values (4.6 and 6) for minimum solubility of protein concentrate, and the lower ionic strength used in Figure 2 makes the concentrate somewhat soluble at pH 4.6 to 6 instead of insoluble. Solubility of 204 concentrate increased rapidly as pH increased above 7; almost all the nitrogen was soluble at pH 10.2. Nitrogen solubility increased as pH decreased below 5.5, and a shoulder in the solubility curve was observed around pH 4.2. Another rapid increase in solubility was observed below pH 3.5, and solubility reached 83% at pH 2.3.

The nitrogen solubility curve of 385 concentrate was similar to that of the 204 concentrate in general, and minimum solubility of the 385 concentrate was also near pH 6 where about 9% of the nitrogen was soluble. The nitrogen solubility of the two concentrates was close between pH 4.2 and 7.3, but solubility of the 385 concentrate was higher above pH 7.3, and almost all nitrogen in 385 concentrate was soluble at pH 9. A shoulder in the nitrogen solubility curve was also seen for the 385 concentrate near pH 4. However, its solubility below pH 4 was lower than that of the 204 concentrate, and 70% of the nitrogen in the 385 concentrate was soluble at pH 2.2.

Hydration Capacity, Emulsifying Activity, and Emulsion Stability. The hydration capacity (weight of sediment/weight of sample) of the 204 concentrate decreased from 4.1 to 3.7 when the extraction pH of the concentrate increased from 10 to 10.8 (Table XX). Hydration capacity was determined according to AACC Approved Methods (1971). The 385 concentrate had a higher hydration capacity than the 204 concentrate extracted at pH 10.8. All concentrates have good hydration capacity.

When extraction pH of the 204 concentrate increased from 10 to 10.8, emulsifying activity and emulsion stability decreased 6% (Table XX). Emulsifying activity and emulsion stability were determined by the method of Yasumatsu et al. (1972) for a simple system; only soybean oil and water were added to the protein concentrate. Emulsion stability was 4% lower than the corresponding emulsifying activity at both pH values. The 385 concentrate had a higher emulsifying activity and emulsion stability than 204 concentrate extracted at pH 10.8. The emulsion stability of the 385 concentrate was 5% lower than its emulsifying activity. A commercial soy protein isolate gave emulsion stability and emulsifying activity values of 45% under the same experimental conditions used for triticale concentrate. Emulsifying activity and emulsion stability of the two triticale concentrates are excellent, and they are much better than those of the soy isolate. Good emulsifying activity and good emulsion stability are important properties of fat emulsifiers in sausage, for example.

Potential Uses of Protein Concentrate and By-Products. Triticale concentrate may find application as a protein ingredient in foods. The attractive hydration capacity, excellent emulsifying activity, and emulsion stability of the concentrate suggest possible use as fat emulsifiers and water-absorbing agents in foods. Since triticale grain and partially dehulled grain have been successfully extruded (Table XII), the residue after one protein extraction (Figure 1) presumably can be extruded into breakfast cereal or snack food, or it may be used as a starch source for fermentation. Pure starch can also be produced (Figure 1) and has potential as a replacement for commercial cereal starches.

CONCLUSIONS

Studies on food uses of triticale carried out at the Northern Regional Research Center and elsewhere suggest that this cereal has considerable promise as a new crop.

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Abstracts of Additional Papers Presented at the Symposium on Nutrients and Flavor Quality of Plant Foods

Following are abstracts of four papers presented at the Symposium on Nutrients and Flavor Quality of Plant Foods but not published. The abstracts are included to give the reader a more complete picture of the Symposium, as it was conceived and presented.

MICROWAVE EXPOSURE AND FLAVOR EVALUATION FOR JUICE CONCENTRATE

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While microwave quanta are nonionizing, intense fields may be concentrated by suitable devices. Masers which act as quantum pumps stimulate coherent beams of energy with fields approaching 10^7 V/cm. Another device is the helical director which can concentrate microwaves into intense, local fields suitable for juice exposure where coherence is unnecessary. The mechanism for microwave interaction is mainly rotation and absorptive polarization which increase the juice energy as responsive portions of the fluid work against constraints provided by the viscous forces. A countercurrent, low-loss helical director system gave quick heating and rapid quenching of the output by the input. A short time constant permitted control in that the thermal inertia is proportionately small. A minimum VSWR was obtained with magnetron current at 250 mA, indicating a satisfactory impedance match and low reflection. The Rieke chart shows that a VSWR of 1.6 at 31.5° toward the load falls on the power contour 1450 W or 90.6% of the power contour through the center. Thus at 25 mA, a typical current, the power was 638 W. The enzymes responsible for pectin degradation were inactivated while microorganisms were destroyed. Flavor evaluation included a test for difference in a trio of unknowns and preference. No significant lessening of acceptability for the exposed juice over the control was found.

A METHOD FOR THE COMPARATIVE DETERMINATION OF THE ECONOMIC EFFICIENCY RATIO IN FOOD PRODUCTS

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The actual problem of malnutrition is not essentially a shortage of food, proteins included. The precise extent of this problem is a matter of distribution in which the income of the consumers plays an important role. The most privileged social classes consume more than enough to cover their nutritional requirements, while the low income groups of the population do not have the means to obtain food in quantity and in quality to meet their nutritional needs. Therefore, it would be very advantageous to have available a procedure that could guide the underprivileged socioeconomic groups to use their economic resources, to buy foods that provide more nutrients at lower price.

This study presents a method for the comparative determination of the economic efficiency ratio of foods (EER), including a system of diagrams to obtain the corresponding economic index. This will allow the selection of the most convenient products from the nutritive as well as the economic point of view.

FORTIFICATION OF WHITE-PAN BREAD WITH OILSEED PROTEIN PRODUCTS: A REVIEW

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Inexpensive high-protein sources have attracted attention as a means of increasing the protein content of foods. Soy flours, concentrates, and isolates are in the market to meet some of the requirements of food processors. Recently, cottonseed, peanut, sesame, sunflower, and others have been added to the list of potential high-protein sources. Bread is a convenient food for oilseed protein fortification. But factors such as (1) kind and type of oilseed protein product used; (2) processing methods and

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