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YIELD AND QUALITY OF CATSUP PRODUCED TO A STANDARD SOLIDS AND CONSISTENCY LEVEL I. METHOD OF DETERMINING THE AMOUNT OF TOMATO SOLIDS REQUIRED

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ABSTRACT

A method has been developed to determine the amount of tomato solids required to make a batch of catsup which contains a given level of total solids at any specified Bostwick consistency. It was developed to determine the factors that control the yield and quality of catsup obtainable from any given raw material, and the effect of the processing procedures used for producing the tomato pulp required for its production. It was also developed for evaluating the production capability of recently released varieties grown under field trial conditions. These subjects will be discussed in a subsequent paper.

INTRODUCTION

The factors responsible for the quality and consistency of catsup have been studied without complete success (Cf. ref.). A review of these studies indicated two areas where different methodology might produce data less difficult to interpret. Most early studies made no attempt to relate their data to the compositional factors of the raw material, and the catsup under study varied in total solids and consistency.

Unpublished project studies conducted by the authors have shown that consistency varies logarithmically with the total solids concentration for tomato products. Therefore, a method which makes catsup to both a constant level of solids and a constant consistency would eliminate these known variables, and should permit the investigator to determine the factors which control this relationship.

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Yield of catsup per unit of raw material used has received only superficial study (Schoenfeld 1950). The restrictions placed on the Bostwick consistency value (USDA 1953) are known to control the amount of tomato solids required in a catsup formulation since neither the sugar, salt, vinegar, nor spices exert much influence on the flow characteristics of the finished catsup. Variable amounts of tomato solids are known to be required to achieve the required total solids level or Bostwick value, but basic evidence to explain this is lacking.

MATERIALS AND METHODS

The following recipe was chosen because it makes an 800 g batch of catsup which was found to be the most manageable and best suited to the laboratory equipment available. Tomato pulp concentrated to contain over 18% of total solids provided the tomato solids required by the formulation. Sugar, salt, 100 grain distilled vinegar, and a powdered spice mixture made up the other ingredients.

Prepare about 1700 g of puree containing exactly 17% total solids by any conventional dilution procedure. Stir thoroughly to obtain a uniform distribution of the tomato solids. Weigh the ingredients required for two portions of catsup as listed in Table 1.

Weigh each batch of the tomato puree into a tared aluminum alloy cooking vessel of about 1500 ml capacity. Weigh each dry ingredient into a separate beaker.

Add the required amount of water to the appropriate cooking vessel and heat the puree-water mixture rapidly, with constant stirring, to 190°F (88°C) using a temperature controllable electric hot plate. Keep the time of heating as constant as possible for both lots.

Table 1. Ingredients required to make two 800 g batches of catsup at 33% total solids, and containing 25% and 40% tomato solids in the total solids, respectively

Ingredient	25% Tomato Solids Formulation		40% Tomato Solids Formulation	
	g Wet Basis	g Dry Basis	g Wet Basis	g Dry Basis
Puree—17% total solids	388.2	66	621.2	105.6
Sugar	181.5	181.5	141.9	141.9
Salt	15.8	15.8	15.8	15.8
Spices	0.66	0.66	0.66	0.66
Vinegar 100 g	40.0	0.4	40.0	0.4
Water	190.0	—	0.0	—
Totals	816.2	264.4	819.6	264.4

When this temperature is reached, remove the cooking vessel from the heat and add the sugar, salt, spices, and vinegar with continual stirring until their complete solution is obtained. Weigh the cooking vessel and its contents, and reheat if the net weight of the contents exceeds 802 g.

Place the cooking vessel in an ice-water mixture and cool, with occasional stirring, to 20°C. Dry the outside of the vessel and adjust the net weight of the contents to 800 g by adding water if necessary. Determine Bostwick values at 20°C (USDA 1971).

The percentage of tomato solids required by a catsup formulation to produce a catsup at any Bostwick value, can be determined graphically. This is done by making a semilogarithmic plot of the Bostwick values determined for the 25 and 40% formulations versus percent tomato solids (Fig.1). In order to make a catsup that flows 6 cm in the Bostwick consistometer at the 33% level of total solids, 36.0% of the total solids must be tomato solids. This batch may be formulated and prepared for analytical use by ratio adjusting the tomato solids to sugar requirements of the formulated batch (tomato solids + sugar = 247.5 g).

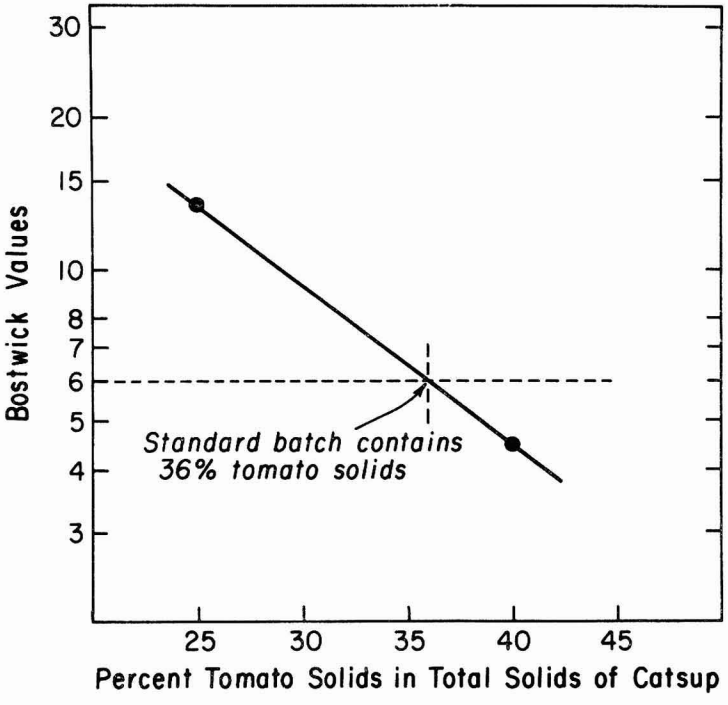

FIG. 1. GRAPHICAL PROCEDURE FOR DETERMINING THE PERCENTAGE OF TOMATO SOLIDS IN THE STANDARD BATCH

RESULTS AND DISCUSSION

The initial studies to develop the described method involved the making of four laboratory scale batches of catsup from the same lot of puree. The total solids content of the finished batches contained 25, 30, 35 and 40% of tomato solids, respectively. A compensatory sugar adjustment was used to hold the total solids content of the finished batch at a constant value. Bostwick values (20°C, 30 s) of the batches were determined and the data were studied graphically. The graphical representation of the data is illustrated in Fig. 2 which shows data derived from batches prepared from puree made by "cold-breaking" and "hot-breaking" VF145 tomatoes from the same harvest lot. These data are typical of all the other data secured in this detailed manner.

These batches were prepared to contain 33% of all total solids, the limiting solids content for a fancy grade catsup, and analytical testing showed them to contain 33 ± 0.1% total solids. The batches prepared using the amount of tomato solids indicated by the graph to test 6 Bostwick when finished were shown to test 6 ± 0.05 cm.

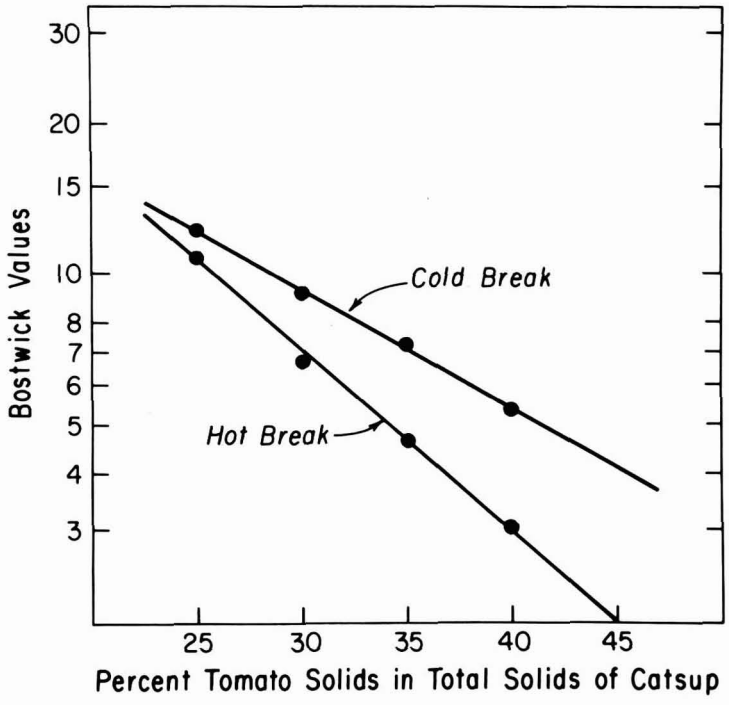

FIG. 2. ILLUSTRATION OF THE PRELIMINARY STUDY UNDERTAKEN BEFORE ADOPTION OF THE PRESENT TWO POINT METHOD

A laboratory batch having a 6 cm Bostwick value at 33% total solids was termed the "standard batch." The percentage of tomato solids required to make this batch is a key value which we chose to call the "yield factor." Knowing the yield factor, the pounds of tomato solids required to produce 100 lb of catsup is easily calculated and the latter value can be easily converted to pounds of catsup per ton of harvested tomatoes. How the yield factor is related to the compositional characteristics of the raw material is of far more significance from a research standpoint, however, since it can be related to production practices, or to the production capabilities of new varieties.

Correlation coefficients for five, four-batch, series averaged 0.995 while the standard error of estimate ranged from 0.09 to 0.34. Therefore, the two batch system was adopted following this method because it was deemed to be sufficiently accurate.

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YIELD AND QUALITY OF CATSUP PRODUCED TO A STANDARD SOLIDS AND CONSISTENCY LEVEL II. INFLUENCE OF HANDLING PRACTICES, BREAK TEMPERATURE AND CULTIVAR

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ABSTRACT

Consistency and serum separation were found to be unrelated quality attributes. When consistency was standardized to a given Bostwick level serum separation varied from none to considerable. Consistency was found to be directly dependent upon the fraction of water insoluble solids (WIS) of the total solids (TS) of the tomato pulp used. Serum separation was found to depend upon the break system employed. Retention of at least 80% of the tomatoes' original serum viscosity was required for minimal serum flow. The data suggested that serum separation best measures quality, whereas the percentage of water insoluble solids in the total solids of a pulp determines the ratio of tomato solids to sugar required to achieve a standardized consistency level, which makes this ratio a measure of yield.

The data also indicate that automation of catsup making is possible provided the "yield factor" is determined by the method described, or the water insoluble solids and total solids contents of the pulp are known beforehand.

INTRODUCTION

It is generally recognized that viscosity of tomato juice, or pulp, is closely related to the pulping procedures used. This concept has evolved from published investigations (cf. ref.) of many workers over a period of many years, and most recently by Foda *et al.* (1970). A pulp of high viscosity and quality is presumed essential for production of consistency-oriented products with low Bostwick values.

Tomato pulp is prepared by a series of operations involving maceration, heat-treatment, and sieving or pressing. Their speed, and the degree and intensity of the heat-treatment controls retention of desirable colloidal components destructible by enzymes and/or heat. Also, the combination of procedures used for carrying out the entire operation additionally controls the size, shape, and amount of suspended particulates in the pulp.

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The first heat-treatment step in the process is commonly referred to as the "break" and has two main objectives. First, it must inactivate the pectinolytic enzyme systems. By proper design this can be accomplished at nearly any rate. Secondly, it softens the tissues to ensure maximum recovery of all extractable components and to produce a suspension of finely-divided cellulosic materials.

Tomato pulp forms the basis of the diphasic suspension referred to as catsup. Catsup is primarily a colloidal serum containing a large proportion of suspended particulates and a large amount of dissolved sugar. Physical and chemical properties of the tomato pulp will determine the amount of it required to produce a catsup which is standardized with respect to total solids and consistency.

A literature review revealed that previous investigators tended to ignore differences in chemical and physical properties of pulps when formulating catsups, thus causing variability in total solids in samples prepared to a constant consistency, or inevitable differences in consistency if prepared to a constant total solids content. It was difficult, therefore to evaluate accurately factors influencing yield (tomato solids used) and quality (consistency and/or response to a blotter).

Since chemical and physical properties of tomato pulps are influenced so strongly by manufacturing procedures, and of late by variety, it seemed desirable to determine how these procedures affected both yield and quality of catsup samples standardized for both total solids and consistency.

MATERIALS AND METHODS

Processing

Tomatoes for these studies were canning varieties including many new cultivars. Those used to obtain the data presented in Table 1 were machine harvested lots of VF145 variety from staggered plantings grown within a 15 mile radius of the pilot plant. The same variety of tomatoes was used to obtain the data in Table 2, but the harvest and handling practices were varied to determine their effect on quality and yield of product. Normally harvest begins when 90% of the tomatoes on the test vines reach a good red color. "Early," in these tests, referred to fruit harvested when only 80% were a good red color. The lots included the pinks but all green and defective fruits were discarded.

The VF145 variety is only medium firm in texture and is easily damaged by the machine and by extended transportation. The 100 miles of transportation reported in the table was provided by a transportation simulator designed for this purpose, (O'Brien *et al.* 1963).

Table 1. Effect of pulping temperature on the yield and quality of catsup produced from tomato paste

Pulping Temperature	Composition of Pulp			Catsup, 33% Total Solids and 6 cm Bostwick Consistency				
				Quality Factor	Yield Factor			
	Total Solids w/w	Water Insoluble Solids w/w	Serum Viscosity cps	Serum Flow on Blotter[1] cm	Percent of Tomato Solids in Formulation. Dry Catsup Solids Basis	Lb of Tomato Solids per 100 lb Catsup. Yield Factor × .33	Serum Viscosity cps	Kramer Shear Press Values lb
225°F(107°C)	6.00	0.69	4.9	4.2	39.7	13.1	22.0	—
77°F(25°C)	6.13	0.61	1.0	9.2	57.3	18.9	3.5	—
225°F(107°C)	4.65	0.80	3.9	4.2	31.8	10.5	—	25.5
77°F(25°C)	4.43	0.57	1.0	9.4	40.6	13.4	—	14.0
225°F(107°C)	4.55	0.62	4.5	4.8	35.7	11.8	27.3	21.5
77°F(25°C)	4.51	0.56	0.9	9.8	50.0	16.5	2.4	13.5
225°F(107°C)	6.30	0.63	5.8	4.8	42.7	14.1	37.0	23.0
160°F(71°C)	6.06	0.62	1.0	9.9	44.8	14.8	2.5	13.0
225°F(107°C)	6.25	0.64	3.3	5.0	46.7	15.4	29.5	19.5
160°F(71°C)	5.98	0.65	1.7	8.9	47.9	15.8	4.4	15.0
225°F(107°C)	5.17	0.54	2.6	4.9	40.6	13.4	21.0	18.1
160°F(71°C)	5.26	0.59	1.8	9.0	42.4	14.0	3.0	12.8
225°F(107°C)	4.85	0.72	3.8	5.2	41.8	13.8	14.8	—
160°F(71°C)	4.84	0.72	1.2	10.7	44.2	14.6	2.5	—

[1]Diameter of wetted spot.

Table 2. Effect of serum viscosity changes induced by handling practices on the performance characteristics of tomatoes for paste production for later use in catsup making

Tomatoes					Catsup, 33% Total Solids and 6 cm Bostwick Consistency			
Harvest Treatment	Hours Before Processing	Serum Viscosity		Washing Loss %	Flow on Blotter[1] (cm)	Kramer Shear Press Values lb	Tomato Solids Required, per 100 lb Catsup lb	Yield lb per Ton Delivered
		Centipoise	% Remaining					
Early machine	20	7.3	100+	2.9	4.4	22.5	13.9	986
	40	8.0		4.0	4.4	22.5	13.2	932
Early, machine	20	7.4	100+	0.5	4.1	22.7	14.5	807
	40	7.5		5.8	4.7	22.0	13.2	820
Normal, hand-picked	20	5.3	100−	0.0	4.4	21.6	14.8	818
	40	5.2		1.6	4.5	24.0	14.5	789
Normal, machine	20	5.1	100+	0.2	4.3	22.0	14.5	858
	40	5.2		1.3	4.7	20.5	14.6	877

Normal, machine, 100 mi. trans.	20	8.0	88	2.7	4.6	23.1	13.7	888
	40	7.0		10.8	4.6	20.2	13.1	820
Normal, hand-picked	20	4.0	85	3.1	4.3	21.5	15.4	718
	40	3.4		0.0	5.2	17.4	14.8	763
Normal, hand-picked 100 mi. trans.	20	3.4	76	0.6	5.9	17.0	14.4	756
	40	2.6		16.5	8.2	15.6	12.4	768
Normal, machine	20	3.0	70	29	6.0	18.0	13.9	707
	40	2.1		11.0	10.1	12.9	13.7	640
Normal, machine and central sort	20	3.0	63	8.1	6.0	19.0	12.8	746
	40	1.9		17.0	10.0	12.7	9.7	859
Early, machine 100 mi. trans.	20	4.6	54	4.6	5.0	20.3	12.3	901
	40	2.5		20.0	9.4	13.7	11.0	829

[1]Diameter of wetted spot

Competitive efforts by companies supplying seed to growers of canning tomatoes have caused the release of many new cultivars based mainly upon field trials. Some of these were used to obtain the data reported in Table 3, and their shape and texture are described by indigenous terms familiar to the industry.

Table 3. Influences of the textural characteristics of tomato cultivars on the yield factor

(1) Cultivar	(2) Shape and Textural Characteristics	(3) Water Insoluble Solids (WIS) (% of Total Solids)	(4) Yield Factor (% of Tomato Solids in Formulation, Dry Catsup Basis)	(5) K Column (3) × Column (4) ÷ 100
VF145-7879B	Round, fairly firm	10.71	51.0	5.46
HS-2	Round, fairly firm	11.76	45.2	5.32
XP-265	Globe, fairly firm	11.36	44.8	5.08
VF145-7879	Round, fairly firm	11.27	47.4	5.34
UC74-18-4	Round, very firm	15.30	35.5	5.43
VF-145-B7878	Round, fairly firm	12.07	44.5	5.37
Peto Mech II	Square round, very firm	15.98	35.3	5.64
VF134	Square round, very firm	13.34	39.3	5.24
GS-2	Round, fairly firm	13.34	40.8	5.44
UC82C	Square round, very firm	14.29	38.4	5.48
GS-12	Round, firm	13.66	39.3	5.34
Castleblock	Blocky, very firm	14.79	36.0	5.32
CX336	Long pear, firm	14.50	37.9	5.50
UC134	Square round, very firm	14.80	36.2	5.36
GS70	Elongated, variable, firm	14.88	35.3	5.25
E3202	Round, firm	10.86	48.5	5.27
VF134-1-2	Square round, very firm	13.34	40.0	5.34

Table 3. (Continued)

(1) Cultivar	(2) Shape and Textural Characteristics	(3) Water Insoluble Solids (WIS) (% of Total Solids)	(4) Yield Factor (% of Tomato Solids in Formulation, Dry Catsup Basis)	(5) K Column (3) × Column (4) ÷ 100
Castlex1601	Plum to round, very firm	13.01	43.0	5.59
Castlex1004	Oblong, egg-shaped, firm	12.87	41.5	5.34
Castlong	Elongated, very firm	14.40	36.7	5.28
M71-5	Square round, very firm	15.12	35.3	5.34
UC105-J	Elongated, very firm	17.06	32.5	5.54
Peto 76	Blocky oblong, very firm	18.22	30.2	5.50
UC82A	Square round, very firm	13.73	38.9	5.34

All lots were washed in chlorinated water and sorted to remove defective fruits to simulate commercial methods. Pulping was accomplished by feeding whole tomatoes at a rate of 13 lb/min into a Reitz disintegrator (Type RA-4-K53, 3/16 in. screen) close coupled to a positive displacement pump (Waukesha Type 25) which was in turn close coupled to a steam injection tee and mixing pump. Temperature was controlled by a thermocouple-actuated recorder-controller with the thermocouple mounted 18 in. downflow from the tee and pump. This was followed by enough 1 in. tubing to provide a 30 s holding period. A back pressure valve at the termination of the holding section prevented temperature drop in the tube. Upon exiting from the hold tube the hot pulp passed into a Brown Citrus Pulper (laboratory scale, 0.033 in.(0.84 mm) perforated screen, 5 lb pressure) for removal of skins and seeds. A water-cooled Cherry Burrell scraped surface heat exchanger followed by a 50-gal. holding tank completed the system. Final product temperature before concentration was approximately 100°F (38°C).

For rapid destruction of enzyme systems (hot-break) the pulping system was operated at 225°F (107°C). For rapid enzymatic alteration of pectic substances (activated hot-break) the system was operated at 160°F

(71°C). The system was also operated at ambient temperature (cold-break) (about 77°F, 25°C). When the resulting three types of pulp were prepared from the same raw material the order of preparation was hot-break, activated hot-break, cold-break to prevent enzyme recontamination.

All lots were concentrated sequentially to about 13% and 18% total solids in a modified 4 ft^2 (0.37 m^2) Pfaudler single effect wiped-surface evaporator operating under a reduced pressure of 28–29 in. (709–735 mm) Hg. Steam jacket and product temperature were 250 (121°C) and 100°F (38°C), respectively. The concentrate was canned, pasteurized at 212°F (100°C), and quickly cooled in ice water.

Catsup samples, standardized to 33% total solids and a 6 cm. Bostwick consistency value, were prepared from 30 to 60 days later from the concentrates by the procedure described by Marsh *et al.* 1979.

Analytical

Methods used for determining the chemical and physical properties of the raw material, tomato pulps and catsup samples, were as follows:

a. Total solids: The equipment and procedure outlined in National Canners Association 1977 Bull. 27-L, pages 39–44 were used without modification.
b. Soluble solids:
   1. Equipment (in addition to that required in "a" above):
      Centrifuge, Sorvall SS-4 with SS-34 rotor, or equivalent
      Centrifuge tubes, 50 ml, Nalgene
      Filter paper, S & S 520B ½, 12.5 cm
      Funnel, analytical, 60°, 75 mm
   2. Procedure: Fill two 50 ml centrifuge tubes with tomato juice or diluted catsup (exactly 1 catsup + $3H_2O$ by weight). Adjust gross weight of tubes to within 0.2 g, cap, and centrifuge at 17500 RPM (3700 × G) for 15 min. Decant serum and filter by gravity through S & S 520B ½ filter paper. Determine total solids of this serum by method "a."
c. Water insoluble solids: The difference between the values determined by methods (a) and (b) corrected as specified by National Canners Association, 1977.
d. Enzyme inactivation by microwave treatment.
   1. Equipment
      Radarange, Raytheon Model 1161 or equivalent, 2450 Mhz, two magnetron type, each magnetron 800 Watt (Raytheon Co. Address unknown)

Beaker, glass, 1000 ml
Dish with cover, Pyrex, 3 qt #026
Balance 3Kg capacity, accurate to 1 g
Pulper-Finisher, 0.033 screen, Food Processing Equipment Co., Kalamazoo, Mich.
Pan for ice bath, enamel or plastic, 12 × 16 × 4 in. deep
Pail, plastic, 1 gal. capacity to receive juice from pulper

2. Procedure: Place 1000 ml beaker containing 500 ml distilled water in back of microwave oven chamber to protect magnetrons. Place 2.5 lb of tomatoes one layer deep in Pyrex dish and weigh without lid (±1 g). Cover dish and place in center of Radarange chamber. Set timer for 9 min and start oven on "high" setting. After 6 min change setting to "low." When cook is complete tomatoes should be soft, with loose skin. Reheat in 3-min increments on "low" setting if any firm tomatoes remain. Remove dish and place in pan containing approximately 2 in. ice until tomatoes reach 30°C. Ice level should be kept ½–1 in. below rim of dish. Remove dish, dry outside, and place (lid removed) on balance. Rinse condensate and tomato splashed on lid into dish and adjust for evaporation loss by adding distilled water to achieve initial weight. Stir and pass this tomato material through pulper two times. It is critical that this juice is not contaminated by raw juice with active enzymes. Juice container, spoons, beakers, centrifuge bottles, funnels and other equipment contacting the juice should be used only for microwave-treated juice with inactive enzymes. Stir well and take a sample for serum preparation.

The manufacturing process for tomato juice may result in dilution or concentration of the product, with a concurrent change in serum viscosity. However, it is possible to calculate the viscosity of the juice as if it had maintained the raw material solids level, that is, if there were no change in concentration. Plot % solids of juice sample on linear axis and corresponding serum viscosity (sv) on logarithmic axis. Draw a line between that point and 0.0% soluble solids, 0.80 cps (viscosity of water at 30°C). Find point on line corresponding to solids level of microwave heated juice, then read predicted serum viscosity from graph. From these data, calculate pectin retention with the following equation:

$$\% \text{ pectin retention} = \frac{\log_{10}(\text{juice SV}) - \log_{10} 0.80}{\log_{10}(\text{microwave juice SV}) - \log_{10} 0.80} \times 100$$

The microwave-heated juice sample is undiluted and its viscosity is assumed to represent 100% retention of pectic materials.

e. Serum Viscosity:
   1. Equipment: Centrifuge, Sorvall SS-4 with SS-34 rotor, or equivalent
      Centrifuge tubes, 50 ml, Nalgene
      Filter paper, S & S 520B ½, 12.5 cm
      Funnel, analytical, 60°, long stem, 75 mm
      Filter paper, glass fiber, 25 mm diameter, Gelman Type AE
      Syringe filtration apparatus, Gelman 25 mm with 25 cc syringe
      Water bath 30 ± 0.05°C
      Viscometer, Ostwald-Cannon-Fenske, sizes 100 and 200 (ASTM 1966)
      Timer, seconds and tenths
   2. Procedure: Fill two centrifuge tubes with juice or catsup (1 + 3 H_2O). Centrifuge at 17,500 RPM for 15 min.
      Decant the supernatant serum and filter by gravity through S & S 520B ½ paper. Refilter using the syringe filtration apparatus. The serum from this apparatus is delivered directly into the small arm of the inverted viscometer tube according to the procedure in ASTM (1966). The remainder of the test was performed according to ASTM without modification.
   3. Calculation:
      Results can be calculated in terms of kinematic viscosity centistokes (cs).
      cs = flow time × k
      where: flow time is in seconds, and k is the calibration constant of the viscometer tube.
      Absolute or dynamic viscosity, centipoises (cps), is calculated according to ASTM (1963).
      cps = cs × d
      Where: d is density (grams per cubic centimeter) of the material being tested. (It is permissible to use density in grams per milliliter.)

f. Bostwick values: The procedure is described by USDA (1971)

g. Kramer Shear Press Extrusion Value:
   1. Equipment:
      Lee Kramer Shear Press with 500 lb ring
      Extrusion cell consisting of a 2 in. diameter cylinder 1.6 in. high with a 0.047 in. diameter orifice ⅛ in. long having an 82° conical entry. The piston was fitted with an O-ring seal.
      Timer, electric, seconds and tenths
      Thermometer, Weston dial type 0–50°C
      Ice bath
      Hot tap water

2. Measurement of extrusion value:
   Assemble the extrusion cell on the instrument. Fill cylinder with product, taking care to minimize entrapment of air bubbles. Adjust speed to the proper setting, (this will vary with each determination but will be about 9 for 32 s, 8 for 42 s, and 7 for 52 s) and measure force required to extrude catsup. Since the speed of the piston could not be set exactly, three runs were made at three different speeds. Stroke times were plotted on log-log graph paper against scale readings from the recorder chart, and the scale reading corresponding to a 50 s stroke time was taken from the plot. The three speeds for tomato product testing should be about 52, 40, and 30 s.

h. Blotter test:
   1. Equipment:
      Hypodermic syringe, 10 ml, plastic, with orifice enlarged to 12 mm.
      Blotter paper, 4½ in. square, 40 mm diam circle drawn in center.
      Caliper, metric.
   2. Procedure:
      Place a blotter on an enamel tray. Fill syringe with 5.0 ml of tomato product and deliver the material onto the center of the circle on the blotter. Tap or tilt blotter gently to fill circle with tomato product. Allow blotter to stand until it has dried, then measure the diameter of the area covered by migrating serum along two axes 90° to each other. Average these two values.

RESULTS

Data reported in Table 1 were derived when equal portions of seven different lots of tomatoes were treated by different pulping procedures. In each case, one portion of each lot was prepared by the hot-break (225°F, 107°C) procedure, while the other portion was prepared by either a cold-break (77°F, 25°C) or an activated hot-break (160°F, 71°C) procedure.

Pulps prepared by the hot-break procedure had serum viscosity values within 5% of the viscosity values derived from the pulp of tomatoes heated in a microwave oven, indicating an almost complete retention of water soluble polymers. Pulps prepared by cold-break procedure or activated hot-break procedure, in contrast, had serum viscosity values close to that of water; enzymatic degradation of viscometric contributors was nearly complete in these pulps.

The data markedly reflect the effect of compositional differences induced by the pulping procedures used on the composition of catsup. Serum viscosities of catsups prepared from pulps produced by the hot-break method were much higher than those produced from pulps prepared by

the other two methods of pulping. Serum flow on the blotter and Kramer Shear Press extrusion values reflected similar induced differences.

The cold-break procedure of pulping tended to contribute less insoluble solids to the pulp than either the hot-break or activated hot-break procedure. Apparently some heat treatment is required to obtain the maximum amount of insoluble solids from any lot of tomatoes.

Catsups produced from pulps made by the cold-break method required more tomato solids to produce the "standard batch" than did those produced from pulps made by either the hot-break or activated hot-break method of pulping. The cold-break method required the use of 20 to 30% more tomato solids for the "standard batch" than pulps produced by the other two methods. The activated hot-break method of pulping, on the other hand, required only 3–5% more tomato solids than pulps produced by the hot-break method.

Data reported in Table 2 were derived to determine the effect of storing machine harvested tomatoes prior to processing upon the yield and quality of catsups. It contains data obtained from catsups prepared from paste made from tomatoes pulped by a hot-break method one day after harvest. Another portion from the same lot of tomatoes pulped by the same method some 40 h later is also represented in Table 2. Storage was under cover at ambient temperature.

Serum viscosities reported are those obtained by the microwave procedure on sub-samples of the lot taken just prior to pulping, both before and after storage. Concentrates made from the pulps were converted to "standard batches" of catsup to derive the data reported in the table.

Various lots studied retained from 100 to 54% of their serum viscosity during the 40 h storage period. Lots which retained more than 85% of their initial serum viscosity after storage showed very little serum flow on the blotter, and Kramer Shear Press extrusion values for both storage lots were nearly identical. Lots retaining less than 85% of their initial serum viscosity after storage, flowed excessively on the blotter and showed large differences in Kramer Shear Press extrusion values.

Data indicate that the amount of tomato solids required to produce 100 lb of 33% total solids catsup at a Bostwick value of 6 was slightly less for all lots that underwent 40 h of storage prior to processing. Loss of liquid materials occurs during storage and subsequent washing steps, causing a slight percentage increase of water insoluble solids in pulps prepared from stored lots. The reduced amount of tomato solids required might at first appear to indicate an economic advantage but this is offset by loss of liquid materials which reduces the percent usable material per ton purchased.

Data reported in Table 3 were obtained in studies undertaken to evaluate processing characteristics of cultivars being considered as replace-

ments for the B7879 strain of VF145. Pulps for these studies were prepared by the steam-injection hot-break procedure. These pulps were converted to concentrated products which were used at a later date to prepare the "standard batch" catsup.

Newer varieties range in texture from moderately firm to extremely firm. Analytically this causes the water insoluble soluble solids fraction in pulps to range from slightly less than 11 to more than 18% of their total solid content (dry weight basis). These markedly different amounts

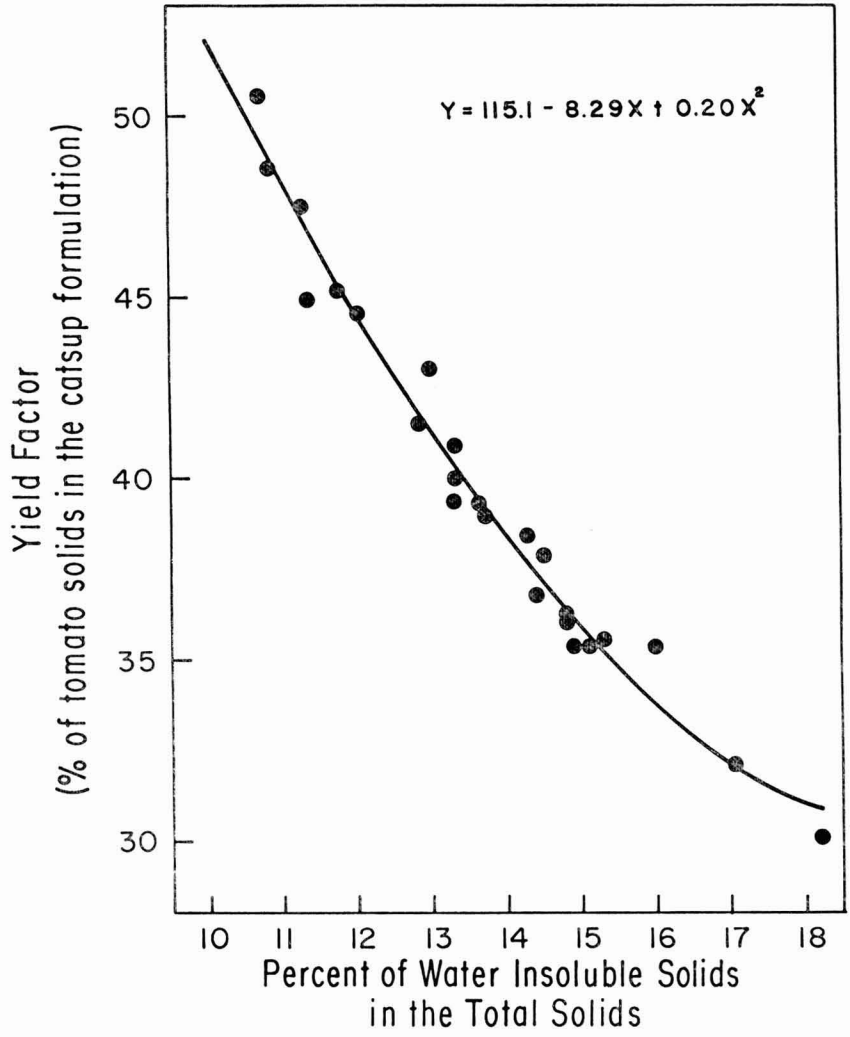

FIG. 1. INFLUENCE OF WATER INSOLUBLE SOLIDS ON YIELD FACTOR.

$r = -0.986$

$S_{yxx}^2 = 0.84$

cause significant changes in standard batch formulation as Table 3 clearly reveals. The amount of tomato solids required as part of the 33% of total solids at Bostwick 6, the yield factor, is shown to be directly related to pecent of these insoluble particulate materials in the total solids of the pulp used. This relationship is illustrated in Fig. 1.

DISCUSSION

Variations in the chemical and physical properties of catsup cause a variety of responses. Two of major importance from a grading standpoint are consistency and serum separation. Both are considered to be grade quality factors under the single heading *Consistency* in the U.S. Standards for Grades (USDA 1953), and are reported respectively, in terms of Bostwick value, and flow of free liquid serum on a test plate.

The definition of consistency in the Standards for Grades refers to "the viscosity of the product and the tendency to hold its liquid portion in suspension." Although a direct correlation is implied between viscosity and serum separation, no correlation exists as the data in Tables 1 and 2 clearly show; $r = 0.30$. Catsups made to a constant level of solids (33%) and a constant Bostwick consistency (6 cm) can have variable amounts of serum flow. If the initial serum viscosity of the tomatoes is not altered by break procedure, or by storage of ripe machine damaged fruits, flow of free liquid from a catsup will be minimal. When it is altered, flow of free liquid depends upon the degree of alteration. Since all of these catsups have 33% solids and a 6 cm Bostwick consistency, they qualify for Fancy grade on a consistency basis, but some fail to qualify on a serum flow basis. The best criterion for judging quality then appears to be the flow of free liquid.

Mechanics of serum separation from catsup are best accounted for by external rather than internal forces. Twigg (1959) suggested that the term lyophoresis (lyo-solution) (phoresis-migration) described the phenomena better than the frequently used term syneresis, hence its use in this paper.

The data appear to indicate that one factor alone is responsible for the quality of a catsup. Retention of serum viscosity by the break method controls the amount of lyophoresis when a catsup is evaluated using the blotter test. Lyophoresis is minimal when pectic enzyme systems are destroyed quickly by a well managed pulping procedure. Lyophoresis is maximal when pectic enzymes are not destroyed, or their rates of reaction are increased by slow temperature increase during pulping. Quality of a catsup, therefore, is related directly to management of the pulping procedure because this controls retention of serum viscosity of product.

Serum viscosity increases in a logarithmic manner that is related to the number of times the solids are increased by concentration. Pulps with high serum viscosities produce catsups with high serum viscosities which exhibit no lyophoresis. The reverse occurs with pulps having low serum viscosities. Lyophoresis is, therefore, a function of the substances contributing to serum viscosity which presumably are largely pectins. Their contribution to Bostwick value, if any, was masked in these tests by producing all batches to the same consistency.

Kramer Shear Press extrusion values differentiate well between lots showing variable amounts of lyophoresis. A standard procedure using this type of equipment could be devised to precisely differentiate rather small differences of quality in terms of serum flow.

The yield of catsup is determined by the percent of tomato solids required for a catsup to reach some specified total solids level and Bostwick value. This value, or factor, determines the yield charcteristic of any lot of tomatoes whether they are handled by differing harvest procedures, processing practices, or whether they are new or old varieties. For comparative purposes in this study, the "yield factor" is defined as the amount of tomato solids required to make a catsup which has a Bostwick value of 6 when total solids are 33 $\pm$ 0.1%. Variable yield data are derivable when the factor has been secured; e.g., lb catsup per 100 lb tomatoes.

Findings of these studies show that this factor ranged from 28 to 58% for the standardized procedures described. No correlation existed between this factor and quality when the latter was measured in terms of lyophoresis, $r^2 = 0.34$. Data show the factor to be related to the method used for pulping tomatoes and to the variety of tomato used. When the same variety was given a cold-break pulping, more tomato solids were required to make catsup than when either activated hot-break or hot-break were used. The latter two methods differed only slightly in requirements. From break-procedure standpoint, yield factor appears to be dependent upon the tomatoes' receiving sufficient heat treatment to soften tissues for the subsequent pulping steps. For maximum yield, pulps containing the highest possible amount of suspended cellular tissues must be produced. Efficient extraction apparently depends upon the tissues being sufficiently softened by the heat treatment.

Why the yield factor varies was disclosed when pulps were produced from various varieties by the same processing procedure. Cultivars listed in Table 3 are some of those being seriously considered as replacements for the presently used strains of VF145. They vary in many attributes but principally in shape and texture; e.g., rounds, squared rounds, or pear shaped that vary from only medium firm to very firm in texture. They also differ in many compositional attributes. One of these, water insoluble solids, can be related to their differing textural characteristics. Firm-

er textured varieties with thick fleshy walls and small locules containing small amounts of locular gel produce pulps that are extraordinarily high in suspended cellular matter. By contrast pulps made from variety VF145 are lower in suspended matter. Table 3 shows that water insoluble solids content varied from 10.7 to 18.2% on a dry weight basis, for cultivars listed.

When purees from these pulps were used to produce the "standard-batch" catsups, a relationship between water insoluble solids content and percent of tomato solids required by the formulation became evident. The lower the water insoluble solids content of the total solids in the pulps, the greater the amount of tomato solids required to make the "standard-batch." Statistical analysis indicated that a second order equation fits the data in Table 3 with the highest degree of correlation and lowest standard error; $r = -0.986$ and $s_{yxx}^2 = 0.84$. When x = the percent of water insoluble solids in the total solids, and y = the yield factor, the equation that best fits the data is $y = 115.1 - 8.29x + 0.2x^2$.

The relationship just discussed is not sharply curvilinear. An estimate of the amount of tomato solids required by a formulation to produce catsup at 33% total solids with a Bostwick value of 6 can be quickly obtained by using the mean of the constants (mK) (Table 3, column 5). It was derived by multiplication of the insoluble solids content (column 3) by the yield factor (column 4) divided by 100 and was found to be 5.38 ± 0.12. This implies a linear fit and is nearly as accurate as use of the curvillinear equation for estimating y. Then the yield factor (YF) for an unknown tomato concentrate is mK divided by the WIS on a dry weight basis as determined in the laboratory, times 100; or YF = (mK/WIS) $\times$ 100.

Catsup is both solids and consistency oriented; yield by any catsup making procedure is determined by the total solids of the pulp and by those substances important in pulp which control consistency. Some commercial manufacturing procedures are designed to produce catsup at a given level of total solids, others are designed to produce catsup of a given Bostwick value. For catsup produced by the first method, the Bostwick value is an uncontrolled variable. For that from the second method, the total solids level is uncontrolled. These data indicate that production procedures could be automated to produce a more standardized catsup provided the ratio of water insoluble solids to total solids of the tomato pulp, or some function related to it, is known beforehand. This would guarantee maximum yield from any lot of raw material.

CONCLUSIONS

When catsups from various tomato lots are produced to both a standardized level of total solids and a standardized level of consistency; quality, as measured by lyophoresis, is related only to the retention of the serum viscosity by the pulping procedure used. When serum viscosity retention ranges between 100 and 85%, lyophoresis is minimal; below 85% lyophoresis increases sharply.

Yield factor, the percentage of tomato solids in the formulation, is related primarily to amount of insoluble cellular material released during the pulping operation. The greater the percentage of insoluble material in the pulp, the less will be the percentage of tomato solids required in the formulation.

When yield is the only concern of the producer, a heat treatment that tends to maximize suspended cellular matter in pulp is important. When concerned with both yield and quality, the producer must devise a pulping procedure that both inactivates pectic enzymes almost instantaneously and produces the maximum amount of suspended cellular matter in the pulp.

Bostwick values measure the consistency of a catsup but fail to measure serum flow. At constant total solids and consistency catsups can have variable serum flow. Consistency is dependent upon the tomato solids fraction of the solids entering its formulation which was found to be dependent upon the water insoluble solids fraction of the total solids content of tomatoes.

Serum flow measures the adequacy of the break procedures to retain serum viscosity values almost unchanged between a sub-sample heated by micro-waves and the pulp produced following the break treatment. It is the sole measure of quality since consistency can be varied by design.

ACKNOWLEDGMENT

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PREDICTION OF DIFFUSION IN SOLID FOODSTUFFS

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ABSTRACT

Diffusion phenomena plays an important role in the extraction of fats and sugar, in the contamination by pesticides or mycotoxines, as well as in other processes like smoking, salting, etc. . . .

In practice diffusion occurs mainly in an unsteady state in strongly heterogeneous, multilayer cellular systems.

The possibility of approximation by the well-known one-dimensional solutions of the second Fick equation has been investigated on model and real systems by computer simulation and by experimentation.

A method is proposed which allows one to determine the influence of the skin of unpeeled fruits and vegetables.

INTRODUCTION

Basically the rate of mass transfer by molecular diffusion in unsteady state can be predicted by appropriate solutions of the second Fick equation:

$$\frac{\partial c}{\partial t} = \text{div } (D \cdot \text{grad } C) \qquad \text{(Eq 1)}$$

Foodstuffs, for the most part have a strongly heterogeneous structure and exact analytical solutions cannot always be found due to the wide variations of the diffusivity of the diffusing substance in the various parts of multilayer cellular systems. That is the reason why it is normally assumed that the transfer is one-dimensional and to correct this assumption by using an "apparent diffusivity," D_a, which can be determined experimentally.

A well known solution of (Eq 1)

$$\frac{C(y \cdot t)}{C^*} = \text{erfc } \frac{Y}{2 \cdot \sqrt{D_a \cdot t}} \qquad \text{(Eq 2)}$$

$C_{(y \cdot t)}$ is the concentration of a given tracer at the height y and at time t.

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This solution is valid if the initial concentration $C_{(y,o)}$ is equal to zero through all the solid material except for y = o where it is constant and equal to C*. It is assumed that C* is in equilibrium with a given surrounding of constant composition.

Another condition for the validity of (Eq 2) is that the Fourier number defined as

$$Fo = \frac{D_a \cdot t}{L^2}$$

is smaller than 0.06. That actually means that the solid can be considered as a semi-infinite body; i.e. that $C_{(L,t)}$ is always negligible.

It is, however, possible to calculate the total mass of tracer $M_{(\infty)}$ which would be picked up by the solid if the concentration was uniform and equal to C*.

If $M_{(t)}$ is the total mass of tracer which has diffused after a time t, it is easily demonstrated that

$$\frac{M_{(t)}}{M_{(\infty)}} = \frac{2}{\sqrt{\pi}} \cdot \sqrt{Fo} \qquad \text{(Eq 3)}$$

Like (Eq 2), (Eq 3) is only valid if Fo < 0.06. It should be pointed out that the mass $M_{(\infty)}$ which corresponds to Fo = ∞ is only used for the purpose of calculation. These equations can easily be solved for D_a and will be used for the interpretation of experimental results.

When D_a is known and Fo > 0.06, other solutions exist which allow the calculation of $C_{(y,t)}$. They can be found in Carslaw (1959), Crank (1970), Tautz (1971), Jost (1972) and Loncin (1978).

It is obvious however that the use of an apparent diffusivity in order to approximate a multidimensional diffusion by a one-dimensional solution is now always valid.

For simple physical models like Fig. 1, it is possible to compute the effect of obstacles on the diffusion profile (Nicolas 1972; Nicolas 1974). If the diffusion takes place upwards, with the concentration at the bottom remaining constant, the concentration at the top can be calculated by a finite-difference solution of the two dimensional second Fick equation.

If on the other hand the transfer is approximated by a one-dimensional solution, the apparent diffusivity which must be taken into account is time-dependent as shown in Fig. 2 (Stahl 1977).

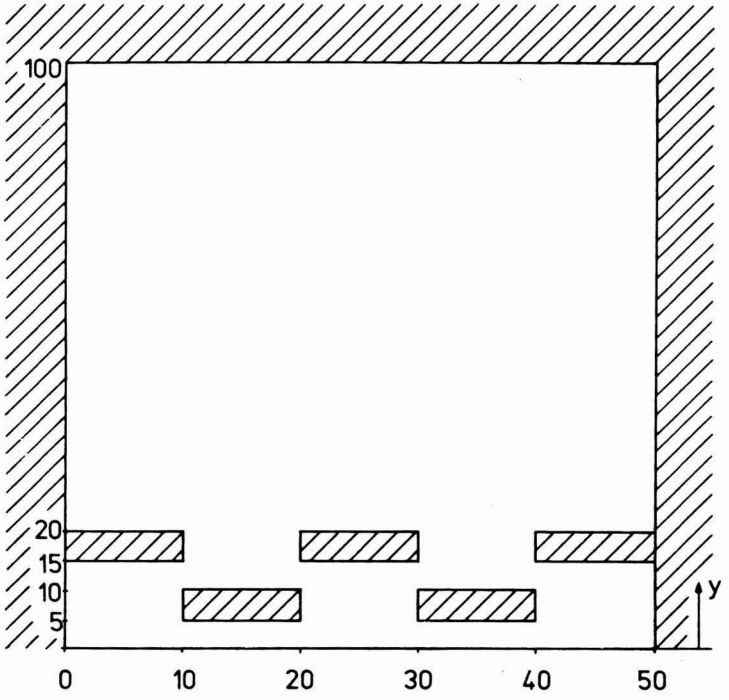


FIG. 1. PHYSICAL MODEL OF DIFFUSION PROFILE

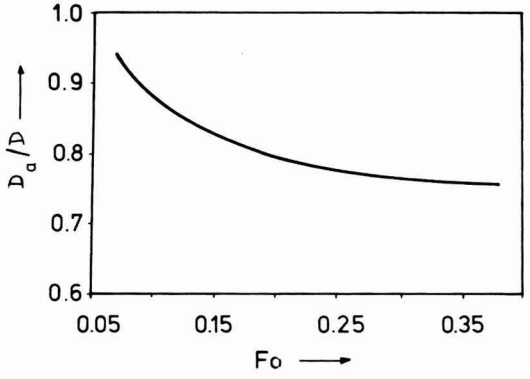
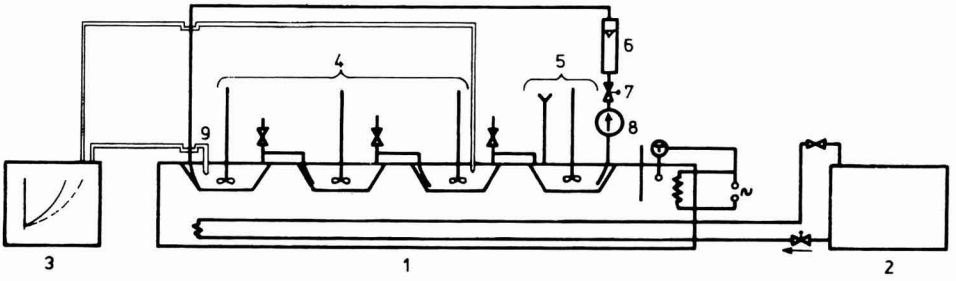


FIG. 2. TIME DEPENDENCY OF APPARENT DIFFUSIVITY

EXPERIMENTAL

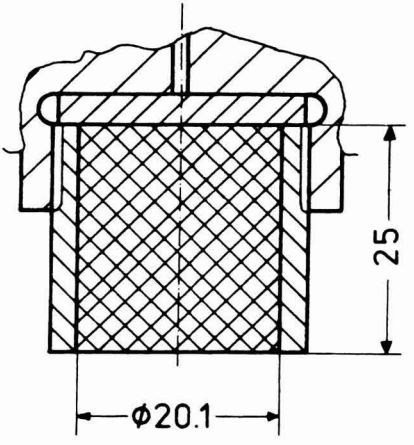
In order to check the validity of the one-dimensional approximation on real systems, experiments were carried out on potatoes, taken as an example of moderately heterogeneous foodstuffs.

The equipment used is shown in Fig. 3. It consists of four pans with stirrers containing an aqueous solution of a tracer. Each pan can receive eight samples of potatoes fitted tightly in a metal cylinder (Fig. 4). The samples are allowed to swell by dipping them in water before each run. A quantity of 0.5 to 1% cyclohexanol was used as a tracer for most of the experiments. The concentration was determined by grinding the whole sample with water and measuring the concentration of cyclohexanol by gas-liquid chromatography (Stahl 1977).



1 Thermostate
2 Kryomate
3 Recorder
4 Stirred pans (with samples)
5 Stirred pan (without sample)
6 Rotameter
7 Valve
8 Pump
9 Thermo-couple

FIG. 3. EQUIPMENT USED TO PREDICT DIFFUSION IN SOLID FOODSTUFFS



(dimensions in mm)

FIG. 4. METAL CYLINDER USED TO HOLD SAMPLES OF POTATOES

RESULTS

Figure 5 shows an example of results obtained as a function of time and of the rotating speed of the stirrer. The slope is 0.5 as predicted by Eq 3. This equation allows one to determine the apparent diffusivity D_a.

In other experiments,the cylindrical sample of potato was cut in slices 1 mm thick which were analyzed separately in order to determine the concentration profile. Figure 6 shows the experimental values. These also allow the calculation of an apparent diffusivity. Figure 7 shows that the correlation between the D_a calculated and the measured values of the concentration profiles is excellent. It shows also that the one-dimensional solutions are reasonably accurate.

It should be pointed out that the apparent diffusivity of cyclohexanol in potatoes is strongly dependent on the variety. For varieties high in water-content it can be as much as 6.10^{-10} m$^2 \cdot$ s^{-1} at 20°C. The diffusivity of cyclohexanol in water has been found to be $8{\cdot}7{\cdot}10^{-10}$ m$^2{\cdot}$s^{-1}. For varieties with a higher solid content the apparent diffusivity is about $2{\cdot}10^{-10}$ m$^2{\cdot}$s^{-1} (Stahl 1977).

The influence of temperature is shown in Fig. 8. The activation energy is 35.7 kJ/mol, about twice as much as for diffusion in water, but similar

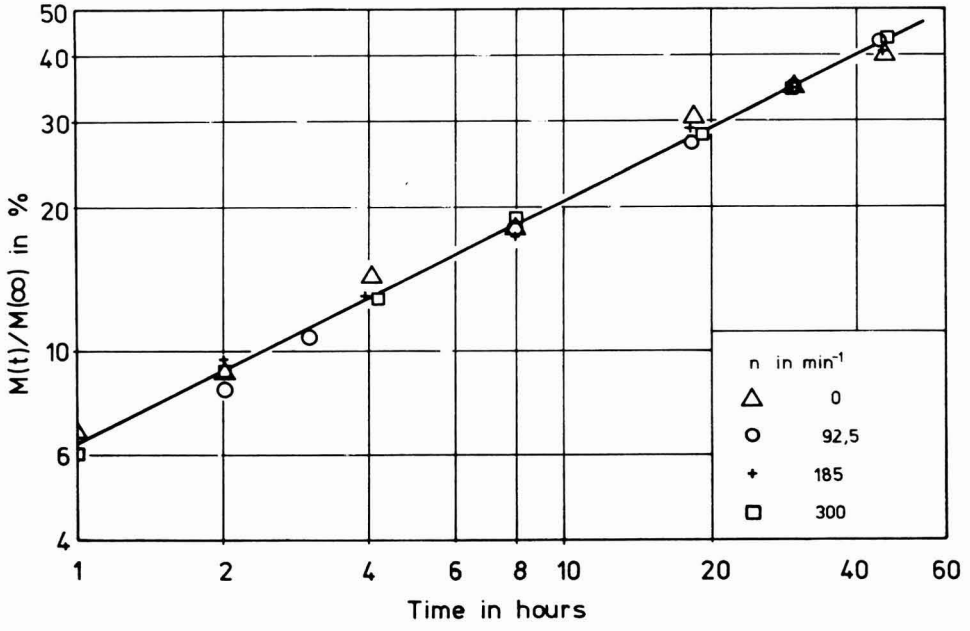


FIG. 5. RESULTS OBTAINED AS A FUNCTION AND THE ROTATNG SPEED OF THE STIRRER

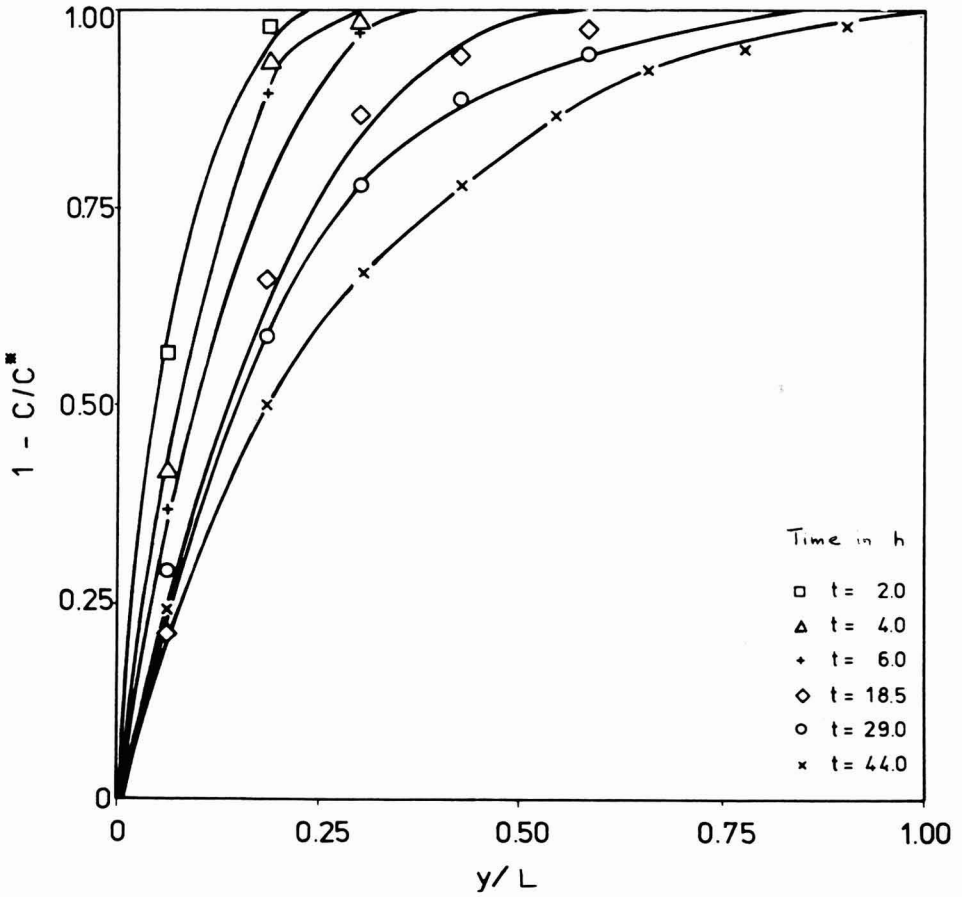


FIG. 6. EXPERIMENTAL VALUES WHEN THE CYLINDRICAL SAMPLE OF POTATO WAS CUT IN SLICES 1 mm THICK

to values measured in lipid membranes. That indicates that mass transfer in potatoes may also be influenced by cell walls and membranes.

The behavior of other tracers is similar to cyclohexanol and an empirical equation has been proposed which allows the prediction of the apparent diffusivity of various tracers (Stahl 1977). In general an increase of chain length of e.g. aliphatic alcohols decreases the diffusivity in water but increases the diffusivity in potato tissues. This is probably due to the influence of lipophilic cell membranes.

INFLUENCE OF THE SKIN

A one-dimensional solution of the second Fick equation of diffusion, however, cannot be applied to unpeeled fruits or vegetables. In the case of

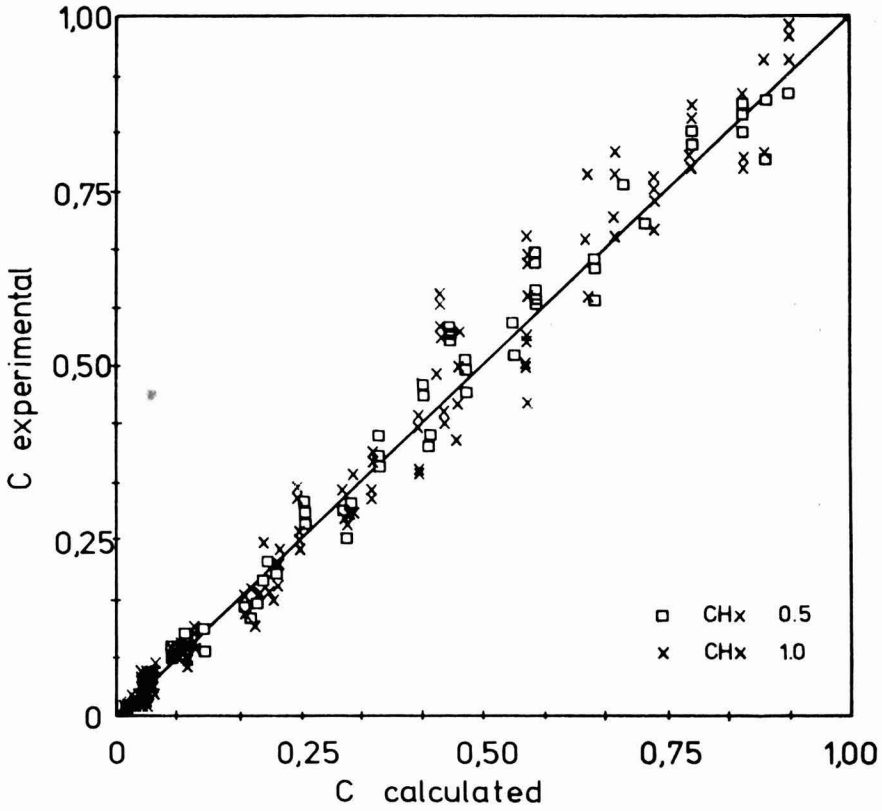


FIG. 7. CORRELATION BETWEEN THE D_a CALCULATED AND MEASURED VALUES OF CONCENTRATION PROFILES

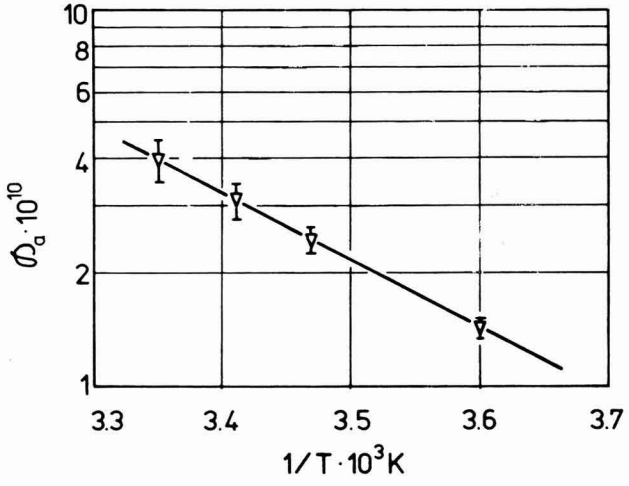


FIG. 8. INFLUENCE OF TEMPERATURE

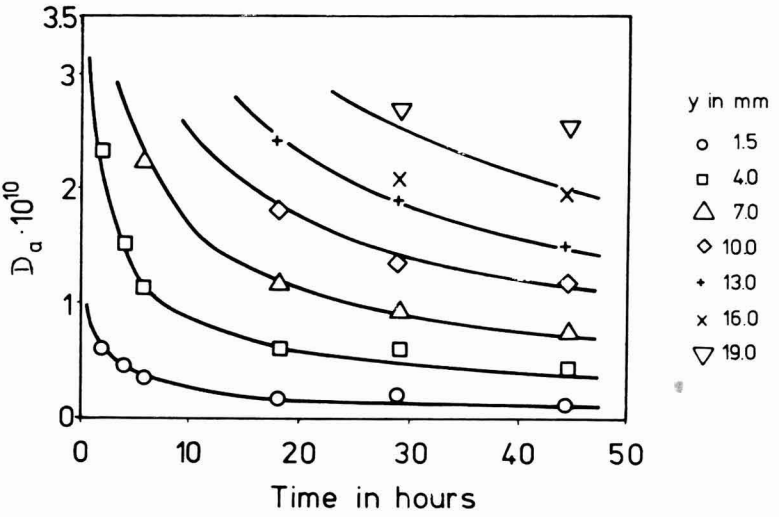


FIG. 9. UNPEELED POTATOES EXAMPLE SHOWING THE EXPERIMENTAL APPARENT DIFFUSIVITY IS DEPENDENT ON TIME AND LOCAL COORDINATE Y

unpeeled potatoes, Fig. 9 shows that the experimental apparent diffusivity calculated from measured concentration profiles with Eq 2 is strongly dependent on the time and local coordinate y, and thus, can never be considered as a constant.

A boundary layer model can be used if the thickness of the skin is small enough. In this case, the mass of the tracer in the skin itself can be neglected in comparison with the mass which diffuses into the flesh. Usually, both the thickness of the skin and the diffusivity of the tracer in the skin are unknown, hence it is convenient to define a mass transfer coefficient of the tracer in the skin as

$$\beta = \frac{\text{Diffusivity of the tracer in the skin}}{\text{Thickness of the skin}}$$

and a Mass Biot number:

$$\text{Bi} = \frac{\beta \cdot L}{D_a}$$

L is the total height of the sample and D_a is the apparent diffusivity of the tracer into the flesh.

Assuming the same conditions as before, concentration equal to zero initally in the flesh and equilibrium concentration constant and equal to C*, analytical solutions can be found based on the analogy between mass and heat transfer.

Using Y = y/L and the same notations as before with Cu (unpeeled) instead of C and Mu (unpeeled) instead of M, the following solutions are possible:

$$\frac{Cu(y \cdot Fo)}{C^*} = \operatorname{erfc}\left(\frac{Y}{2 \cdot \sqrt{Fo}}\right) - e^{Bi \cdot Y + Bi^2 \cdot Fo} \cdot \operatorname{erfc}\left(\frac{Y}{2\sqrt{Fo}} + Bi \cdot \sqrt{Fo}\right) \quad \text{(Eq 4)}$$

and

$$\frac{Mu\,(t)}{Mu(\infty)} = \frac{2}{\sqrt{\pi}} \cdot \sqrt{Fo} \cdot \left\{1 - \frac{\sqrt{\pi}}{2 \cdot Bi \cdot \sqrt{Fo}} \cdot (1 - e^{Bi^2 Fo}) \cdot \operatorname{erfc}\, Bi \cdot \sqrt{Fo}\right\} \quad \text{(Eq 5)}$$

These solutions are valid even if Fo defined as $D_a \cdot t/L^2$ is larger than 0.06.

It is obvious that (Eq 4) and Eq 5) cannot be solved for Bi. That is the reason why (Eq 4) has been transformed into:

$$Cu\,(Y \cdot Fo) = C(Y \cdot Fo) \cdot (1 - X) \quad \text{(Eq 6)}$$

The expression X is defined by comparing (Eq 2) and (Eq 4). It has been found, however, that an excellent approximation is:

$$X = \frac{1 \cdot 4}{Bi \cdot Y} \cdot 1n\ C(Y \cdot Fo) \quad \text{(Eq 7)}$$

Figure 10 shows the relationship between this approximation and the exact solution.

Likewise (Eq 5) can be written:

$$Mu\,(t) = M\,(t) \cdot (1 - \xi) \quad \text{(Eq 8)}$$

and it has been found that ξ can be accurately approximated by

$$\xi = (1 + Bi \cdot \sqrt{Fo})^{-1} \quad \text{(Eq 9)}$$

as shown in Fig. 11.

In addition (Eq 7) and (Eq 9) can be solved easily for Bi, which allows one to express the influence of the skin on the diffusion.

CONCLUSIONS

In solid foodstuffs with a moderately heterogeneous structure, like peeled potatoes, the diffusion phenomena can be predicted by the well-known solutions to the second Fick equation using an experimental apparent diffusivity.

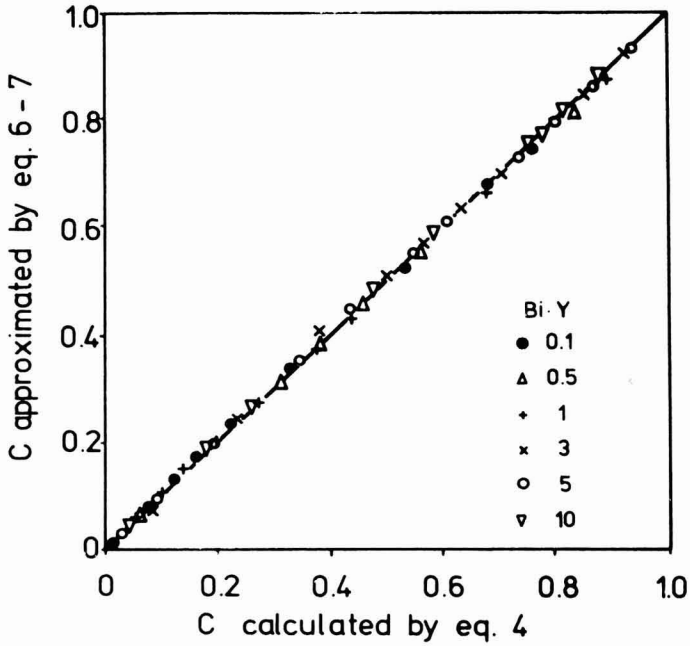


FIG. 10. RELATIONSHIP OF C AS CALCULATED BY EQUATION 4 AND APPROXIMATED BY EQUATIONS 6–7

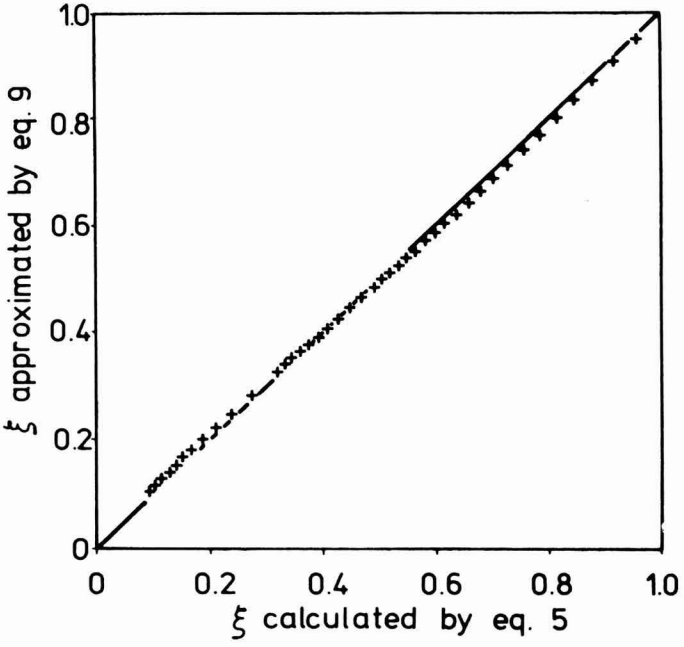


FIG. 11. RELATIONSHIP OF XI CALCULATED BY EQUATION 5 AND APPROXIMATED BY EQUATION 9

In the case of unpeeled foodstuffs, a boundary layer model allows one to describe the influence of the skin which can be expressed easily by a dimensionless mass Biot number.

Approximations have been found by the comparison of diffusion rates in peeled and unpeeled products. These approximations, although very simple, are very accurate and allow one to predict diffusion phenomena without the aid of a computer.

SYMBOLS

a	subscript for apparent	
Bi	Biot Number	Dimensionless
Co	Concentration	Various units
D	Diffusivity	$m^2 \cdot s^{-1}$
Fo	Fourier Number	Dimensionless
M	Mass	kg
t	Time	s
u	Subscript for "unpealed"	
T	Temperature	K
y	Coordinate	m
Y	Coordinate (dimensionless = y/L)	
X and ξ	defined by equations 6 and 8	

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SEASONAL VARIATIONS IN PROTEIN FRACTIONS, YIELDS AND QUALITY OF LEAF PROTEIN CONCENTRATES EXTRACTED FROM PASTURE HERBAGE

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ABSTRACT

Permanent pasture stands were used for protein extraction in laboratory-scale operation during the spring, summer and autumn seasons. Mixed herbage was in its 3rd, 4th, 5th and 6th weeks of regrowth. Efficiency of the protein extraction process at different stages of herbage maturity was measured within each season as well as the nutritional and biochemical characteristics of the recovered protein.

Significant interaction between the seasons and herbage regrowth stage was observed in relation to a number of measurements of efficiency of protein extraction. In general however, protein recovery declined with herbage maturity. Significantly less leaf protein concentrate (LPC) with lower nitrogen content was produced from yields of herbage in the summer season as compared to that harvested and processed in either the spring or autumn.

To achieve a PER value similar to casein protein, LPC produced in spring and autumn had to be supplemented with DL-methionine and L-lysine while to obtain similar PER with summer produced LPC it was necessary to supplement LPC with L-tryptophan in addition to L-lysine and DL-methionine.

Juice from spring and autumn-grown herbage showed high proportion of low molecular weight protein fractions as compared to summer where there was a substantial increase in high molecular weight proteins with simultaneous decrease in low molecular weight fractions.

INTRODUCTION

It has been shown that the protein extraction from pasture herbage has potential for production of protein in leaf protein concentrate (LPC) form and that such a protein may be used as a feasible feedstuff for monogastric animals (McKenzie 1977, 1978; Ostrowski 1979).

There were indications however that the efficiency of protein extraction as measured by protein recovery from pasture may be affected by

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both the season of the year when herbage is grown and regrowth stage at which pasture is cut for protein extraction purpose (Ostrowski 1975, 1976c; Ostrowski *et al.* 1975). Similar observations have been made by Onwubuya (1976) in reference to perennial grasses which is one of the species grown in mixed pasture sward. Since quantity of leaf protein concentrates extracted from pasture may be associated with variation in protein fractions—hence with the quality of extracted protein, therefore this aspect of protein extraction has been studied in this paper taking into account the effect of the season of the year on yields of LPC recovered from herbage at varying pasture regrowth stages. Also nutritional quality of extracted proteins has been examined in relation to their biochemical chatracteristic.

MATERIALS AND METHODS

Pasture

A permanent stand of irrigated pasture growing on a mixture of sandy loam and clay soil types was used as a source of herbage. Botanical composition of pasture sward as determined at fifth week of the herbage regrowth is given in Table 1.

The characteristic of climatic conditions recorded during the experiment is presented in Fig. 1. Pasture was topdressed in autumn with 30 kg N/ha in the spring and in autumn with 30% potassic superphosphate at 360 kg/ha. Annual pasture dry matter (DM) production was 1.76×10^4 kg/ha which is characteristic to high DM producing grasslands.

Table 1. Botanical composition of pasture[1]

	(Percent dry matter)		
	Spring	Summer	Autumn
Perennial ryegrass (*Lolium perenne*)	13	1	4
Paspalum dilatatum	2	8	2
Mercer grass (*Paspalum paspaloides*)	5	23	10
White Clover (*Trifolium repens*)	47	55	61
Other grass species	29	0	15
Weeds	1	0	4
Dead matter	3	13	4

[1]Determined in 5th week of pasture regrowth

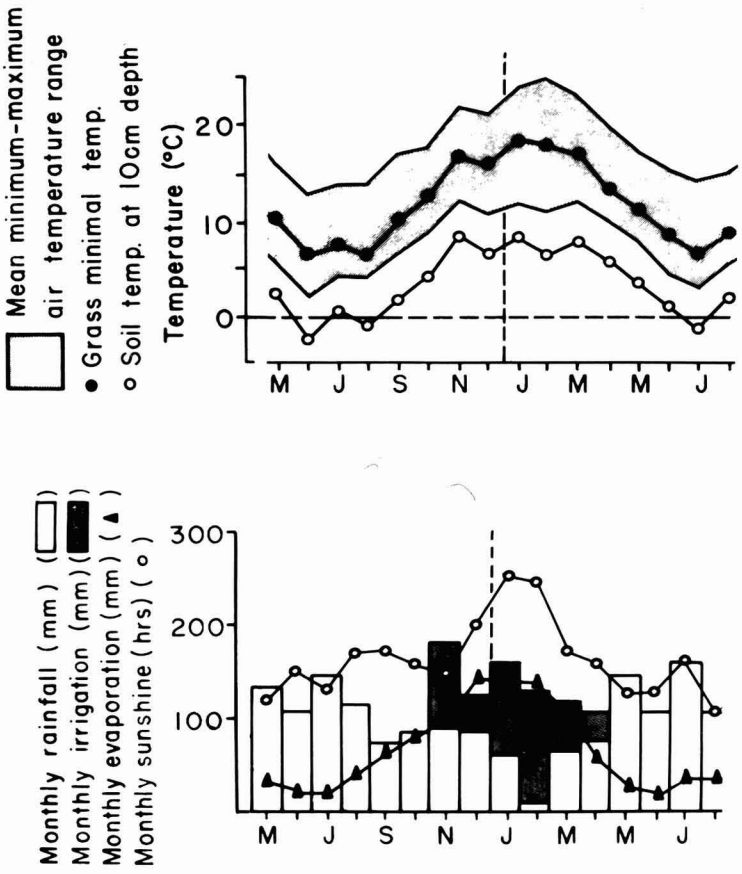

FIG. 1. CLIMATIC CONDITIONS DURING THE EXPERIMENT
Shadowed area within two solid lines indicates difference between monthly mean highest and lowest recorded air temperatures. Shadowed columns built on rainfall figures indicate irrigation (mm).

Herbage Sampling

Laboratory-scale protein extraction was performed by cutting herbage samples from the subdivided plots within the pasture block in the spring (November/December 1977), summer (January 1978) and autumn (March 1978) seasons during four consecutive weeks when the herbage was in its 3rd, 4th, 5th and 6th week of regrowth. Herbage was cut with a pair of hand clippers leaving a stubble approximately 1 cm in height.

Herbage Processing

In order to eliminate "climatic" variability in protein extraction from herbage sampled in various seasons of the year the freshly cut herbage leaves were processed after previous saturation with moisture, i.e. at the stage of complete herbage moisture capacity.

Immediately after being harvested, herbage samples were allocated in ice-cold water for 30 min and then after drainage were macerated in the mincer followed by dejuicing when standard pressure was applied on calico sock located in perforated steel drum.

The juice expressed from herbage was then filtered by passage through a sieve (0.1 mm) and sampled for analysis, and/or used for further processing.

Protein Separation from Herbage Juice

Juice samples were precipitated at 85°C by steam injection in a glass laboratory precipitation chamber. After cooling by passing the juice through a glass coil immersed in cold water, precipitated coagulum was separated from the supernatant by filtration through a Buchner funnel under vacuum using Whatman No. 54 filter paper. Leaf protein concentrates were obtained by freeze-drying separated protein coagulums, and the yields of dry matter recovered from herbage was determined. The freeze-dried LPC's were used for further chemical analyses.

Analytical

Total dry matter content in herbage and juice was determined after heating in a forced-draught oven at 110° for 24 h. Total nitrogen (TN) was determined using the Kjeldahl method as described by the Association of the Official Agricultural Chemists (AOAC 1965). Protein nitrogen (PN) was determined by mixing freshly extracted juice with an equal volume of the solution of 20% (w/v) trichloroacetic acid (TCA) and 2% (w/v) silicotungstic acid (STA). The precipitant curd layer was separated by centrifugation for 15 min at 3,000 rpm at 5°C. The TCA/STA precipitants after centrifugation were used for precipitable dry matter determinations and the supernatants for TCA/STA-soluble nitrogen analysis according to the Kjeldahl procedure used for TN determination. Precipitable nitrogen was calculated from total juice nitrogen subtracting TCA/STA soluble nitrogen.

Ash was determined as the residue remaining after heating in a muffle oven for 18 h at 600°C. Total soluble sugars were analyzed using procedure with anthrone indicator.

Methionine was determined by the Lorenzo-Andreu (1961) procedure and methionine availability by the method described by Pieniazek *et al.* (1975), total and available lysine as described by Ostrowski *et al.* (1970) and tryptophan by using the procedure described by Matheson (1974). Tryptophan availability was determined using *Tetrahymena pyryformis* according to Boyne *et al.* (1975). *In vitro* digestibility was determined by a two-stage pepsin-trypsin digestion procedure according to Saunders *et al.* (1973). Amino acids were determined using the analytical and sample preparation procedures recommended by Byers (1971a, b) for protein concentrates analysis. The Gradipore gel electrophoresis technique on a multi-sample cell with an increasing polyacrylamide concentration (linear gradient 25–27%) and with a 4–6% gradient of cross-linkage in the direction of the electrophoretic flow was used for separation of protein fractions in the juice extracted from herbage. Separations were made at 100 volts in the phosphate buffer pH 8.5 during 45 min followed by staining with the use of an amido black dye. Nutritional value of protein in LPC's was determined using rats (AOAC 1965).

Statistical Analysis

In all trials the herbage subsamples and extracted juices (each being treated as a replicate) were separately processed and chemically analyzed. Results were statistically analyzed using Duncan's multiple range test.

RESULTS

Season of the Year and Herbage Regrowth Stage

While there were no significant differences in herbage DM and TN content due to season of the year neither in DM content of the extracted herbage juice there was significantly higher ($P < 0.05$) nitrogen concentration in the juice extracted from autumn grown herbage as compared to juice from summer grown one (Table 2). This, despite the relatively constant both dejuicing figures and DM of the extracted juice which have not been affected by the season of the year ($P > 0.05$). Significant interactions season × regrowth stage have been detected in herbage DM and nitrogen contents. Yields of extracted protein in LPC form from the unit of herbage DM were significantly lower ($P < 0.05$) in summer as compared to spring and autumn with highly significant ($P < 0.01$) interaction due to pasture regrowth stage (Table 3). Spring pasture was most productive in terms of yield of protein per unit of pasture area as com-

Table 2. The effect of the season of the year on the yields of pasture herbage and chemical characteristics of the herbage and extracted juice at different pasture regrowth stages

		Stage of Regrowth (weeks)					Significance of Differences[2]		
	Season[1]	3	4	5	6	S.E. (±)	Season	Regrowth Stage	Interaction
Yield of herbage DM (kg from 10 m² pasture)	Sp	0.59	1.21	1.86	2.43		Not determined		
	Su	0.42	1.01	1.88	2.07				
	Au	0.26	0.55	0.86	1.12				
HERBAGE	Sp	10.7	11.3	12.8	13.6				
Dry matter (%)	Su	11.8	13.6	14.0	15.7	1.2	NS	*	*
	Au	11.1	12.4	13.5	14.0				
Total nitrogen	Sp	0.37	0.45	0.57	0.59				
(g/100 g fresh	Su	0.39	0.57	0.58	0.56	0.037	NS	*	**
herbage)	Au	0.38	0.51	0.63	0.65				
Volume of juice as %	Sp	45	48	50	50				
of fresh herbage	Su	47	49	48	49	2.8	NS	NS	NS
(dejuicing)	Au	46	48	48	50				
JUICE	Sp	7.38	6.59	6.66	7.07				
Dry matter (%)	Su	7.28	6.94	6.42	6.09	0.34	NS	NS	NS
	Au	7.00	6.98	7.31	7.00				
Total nitrogen	Sp	0.37	0.40	0.44	0.43				
(g/100 ml juice)	Su	0.34	0.43	0.40	0.36	0.016	*	*	*
	Au	0.39	0.44	0.50	0.48				

[1]Sp—Spring; Su—Summer; Au—Autumn
[2]Based on season × regrowth stage interaction as an "error" at 6 d.f.
*P < 0.05; **P < 0.01; NS not significant

pared to other two seasons of the year, with autumn pasture being inferior to spring and summer grown due to slower growth of herbage observed in autumn (see yield of herbge DM). In each season maximum yield of protein from unit of pasture area was achieved at 5th week of herbage regrowth.

LPC Chemical Composition

The chemical composition of freeze-dried LPC's obtained in three seasons indicates that apart from the total nitrogen concentration being highest in the LPC produced in autumn, the soluble sugar content being lowest in summer and highest in the spring season (Table 4) there were

Table 3. The effect of the season of the year on the efficiency of protein extraction procedure as measured by yield of protein (N × 6.25) recovered during processing of pasture herbage

		Stage of Regrowth (weeks)					Significance of Differences[2]		
	Season[1]	3	4	5	6	S.E. (±)	Season	Regrowth Stage	Interaction
Yield of Protein (N × 6.25)									
g/kg herbage DM	Sp	112	77	59	34	7.1	*	**	**
	Su	77	46	32	24				
	Au	93	62	50	33				
g/10 m² pasture area	Sp	66	93	110	83	8.6	*	*	NS
	Su	32	46	60	50				
	Au	24	34	43	37				

[1]Sp—Spring; Su—Summer; Au—Autumn
[2]Based on season × regrowth stage interaction as an "error" at d.f.
*P < 0.05; **P < 0.01; NS not significant

Table 4. Chemical composition of the freeze-dried leaf protein concentrates as obtained from pasture herbage cut in three seasons of the year[1]

				Amino Acids (g per 100 g Recovered Amino Acids)		
Season of the Year	Total Nitrogen (% DM)	Organic Matter (% DM)	Soluble Sugars (% DM)	Sulphur Containing	Lysine	Tryptophan
Spring	6.6 ab	87.9 a	15.7 a	3.2 a	5.6 a	1.9 a
Summer	6.2 b	85.2 a	5.2 b	2.5 b	4.8 a	1.3 b
Autumn	6.9 a	88.3 a	10.4 ab	2.9 ab	5.0 a	1.8 a
S.E. of mean differences	0.21	2.9	2.7	0.17	0.25	0.13

[1]Each value represents the mean of two LPC samples (each analyzed in duplicate), each of which was obtained as a result of protein extractions from pasture samples in the fifth week of regrowth. Values in the same column with unlike superscripts indicate significant differences at P < 0.05 as determined using Duncan's multiple range test.

no significant differences in organic matter and lysine content due to the season of the year when LPC was produced. Sulphur containing amino acids and tryptophan concentrations were significantly lower in LPC produced from summer grown pasture as compared to spring and autumn seasons.

Nutritional Characteristics of LPC

Nutritional evaluation of the protein concentrates produced from herbages grown in three seasons of the year (Table 5) indicate that LPC obtained from summer grown pasture were inferior to LPC's produced in spring and autumn in terms of *in vivo* digestibility, tryptophan availability and protein efficiency ratio (PER). To achieve PER values similar to casein protein it was necessary to supplement LPC's produced in spring and autumn with synthetic lysine and methionine while to obtain similar effects with summer produced LPC, a supplementation with L-tryptophan was necessary in addition to L-lysine and DL-methionine. The total essential amino acid content of the LPC obtained in summer season

Table 5. Nutritional characteristics of LPC extracted from pasture herbage in its fifth week of regrowth in three seasons of the year

Measurement	Season[1]			S.E. of Mean Differences
	Spring	Summer	Autumn	
Protein digestibility (%)				
in vivo	73 a	67 b	76 a	1.8
in vitro	85 a	84 b	85 a	1.9
Availability (%)				
Lysine	79 a	77 a	80 a	2.8
Methionine	87 a	82 a	88 a	3.1
Tryptophan	75 a	62 b	79 a	3.4
Protein Efficiency Ratio (PER)[2] of the diet with LPC supplemented with:				
DL-Methionine (0.2%)	2.1 aA	1.4 bA	1.9 aA	0.14
DL-Methionine (0.2%) + L-Lysine (0.5%)	2.7 aB	2.2 bB	2.8 aB	0.15
DL-Methionine + L-Lysine + L-Tryptophan	2.8 aB	2.7 aC	2.7 aB	0.17
S.E. for amino acid supplementation within the season (for capital superscripts)	(0.18)	(0.16)	(0.20)	

[1]Each value represents mean of the four determinations. Values in the same line with unlike superscripts (small letters) show significant differences at $P < 0.05$ as determined using Duncan's multiple range test. *For PER indication only*—unlike superscripts—capital letters in the same column (within the season) indicate significant differences in PER values due to LPC's supplementation with amino acid(s)

[2]Casein control group PER: 2.8; All groups of animals fed LPC without amino acid supplementation gave negative weight gains

was significantly ($P < 0.05$) lower with less histidine and tryptophan than in LPC produced from herbage grown in spring and autumn, while the concentration of the other amino acids did not differ statistically (Table 6).

Protein Fractions in the Extracted Juices

Five distinctive protein fractions were separated from juices extracted in all three seasons of the year (Fig. 2). Juice from spring and autumn grown herbage showed higher proportion of low molecular weight proteins (fractions labelled 4 and 5) as compared to summer one where there was a substantial increase in high molecular weight proteins (fractions 1, 2 and 3) with simultaneous decrease in concentrations of low molecular proteins labelled 4 and 5.

DISCUSSION

Season of the Year

The results obtained in the present experiment show that much more protein can be recovered from the unit of herbage DM as grown and

Table 6. The essential amino acid profile of leaf protein concentrates extracted from pasture herbage in three seasons of the year[1]

Essential Amino Acid	Season[2]			S.E. of Mean Difference (±)
	Spring	Summer	Autumn	
Histidine	47 a	27 b	105 c	6
Isoleucine	97 a	101 a	100 a	9
Leucine	200 a	209 a	203 a	14
Lysine	113 a	106 a	107 a	7
Total aromatic amino acids	223 a	220 a	220 a	12
Total sulphur amino acids	65 a	55 a	62 a	5
Threonine	85 a	94 a	91 a	6
Tryptophan	38 a	29 b	38 a	3
Valine	132 a	137 a	134 a	8
Total Essential Amino Acids (TEAA) (g per 100 g recovered)	47.1 a	43.2 b	44.8 a	4.8

[1]The value for each amino acid is expressed as the ratio of the weight of amino acid to the weight of all essential amino acids (A/E ratio, mg g^{-1})

[2]Each value represents the mean of four determinations. Values in the same line with unlike superscripts indicate significant differences at $P < 0.05$ as determined by Duncan's multiple range test

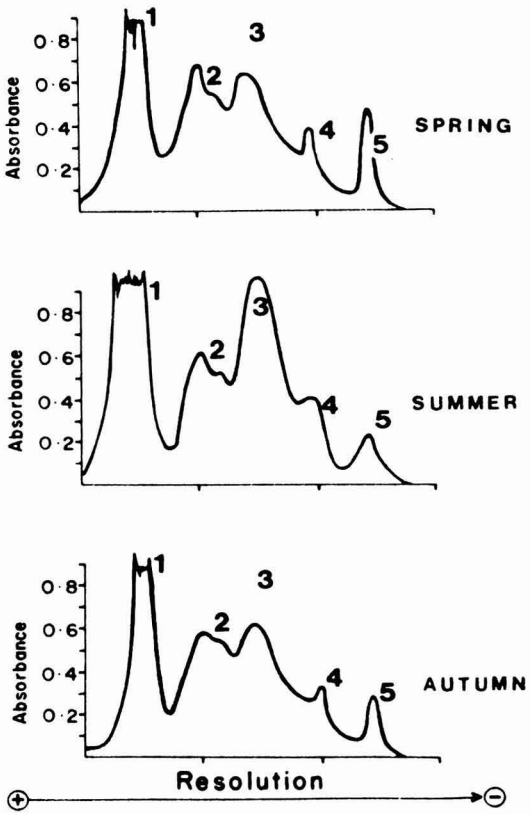

FIG. 2. DISTRIBUTION OF PROTEIN FRACTIONS IN JUICES EXTRACTED FROM SPRING-, SUMMER- AND AUTUMN-GROWN PASTURE HERBAGES AS DETERMINED BY GRADIENT GEL ELECTROPHORESIS

processed in spring as compared with summer and autumn. These results are in agreement with those reported by McKenzie (1977) who showed that despite the topdressing, recovery of protein from mixed pasture in Victoria decreased substantially as the season progressed towards the summer. Extractability of protein from spring grown pasture obtained in its fifth week of regrowth (59 g/kg herbage dry matter, respectively) was consistent with corresponding figures recorded earlier by McKenzie (1977) (61 g dry weight) at a similar season and with a similar cutting time and percentage white clover in the sward.

Maturity of Herbage

The reduction in both extractability and yields of protein from herbage of increasing maturity recorded in all seasons is consistent with observa-

tions of other workers (Allison and Vartha 1973; Arkcoll and Festenstein 1971; Pirie 1971; Oke 1973), who were using different pure crops of herbages. Higher fibre content with increasing maturity reduced the efficiency of cell rupture in the macerator and protein may also be trapped by fibrous material during juice extraction in the press (Arkcoll and Festenstein 1971; Lexander *et al.* 1970). However, despite the decrease in yield of protein extracted from the unit of herbage DM weight with longer periods of pasture regrowth, more matured herbage produced higher herbage dry matter yields. Thus the decision about the optimum herbage stage for protein extraction purpose has to be a compromise between the yield of dry matter and the diminishing protein extraction rate (as measured by yield of protein per unit of processed herbage dry matter). In this experiment, despite the season of the year, those "optimums" were established as week five of pasture regrowth. One week delay in pasture cutting beyond the established "optimum" regrowth stage resulted in approximately 15 to 25% decrease (depending on season) in quantities of protein recovered from the unit of pasture area. This was despite the progressive increase in yield of pasture dry matter. At the same time protein yield expressed per unit of processed herbage dry weight decreased as much as approximately 25 to 42%. This indicates that the maturity of herbage is one of the most important factors to consider from an extraction efficiency point of view. The results obtained were consistent with similar reports by Allison and Vartha (1973), Arkcoll and Festenstein (1971), McKenzie (1977), Oke (1973) and Pirie (1971) who studied several pure stands of herbages, both perennial and legumes in different agronomical conditions.

Quality of LPC

In general, the concentrations of the essential amino acids detected in LPC's produced in the three seasons of the year were in the range of concentrations reported by Byers (1971b) except for the histidine, lysine and threonine values. Byers' (1971b) sulphur containing amino acids figures lower than those detected in this work are also lower as compared to those reported by Bickoff *et al.* (1975). This is probably due to the uncertain cystine values reported by Byers (1971b) in her study. A number of authors have indicated that on average the amino acid compositions of protein concentrates extracted from various plants do not show large variations (Byers 1971b; Gerloff *et al.* 1965; Hollo 1969; Hove 1972; Girault 1973; Parrish *et al.* 1974), and this has been confirmed by the data reported here in reference to pasture of botanical composition which varied from season to season.

Both *in vivo* and *in vitro* digestibilties of the LPC's obtained in three

seasons of the year were in the range of values reported by Byers (1971b), Subba Rau *et al.* (1969, 1972) and Hartmann *et al.* (1967) to be satisfactory for such a type of product, but lower than those reported by Akeson and Stahmann (1965) and Saunders *et al.* (1973).

The total essential amino acids and chemically determined lysine availability, correspond with the nutritional value of LPC's measured in biological tests with rats. A similar relationship between PER values and amino acid composition of proteins was shown by Hansen and Eggum (1973) and Sikka *et al.* (1975) and between PER and chemically determined lysine availability was also reported (Ostrowski *et al.* 1972). These results obtained in this study with LPC's produced in spring and autumn agree with those reported by Hanczakowski (1974), Saunders *et al.* (1972), and Subba Rau *et al.* (1972) who showed that protein concentrates from green plants supplemented with methionine alone or methionine with lysine, were nutritionally equivalent to casein. However LPC obtained from summer grown herbage needed synthetic tryptophan in addition to lysine and methionine to increase the PER value of LPC to the value observed with casein.

Comparison of the amino acid composition of both LPC's with the provisional FAO-WHO standards (1973) indicated that generally sulphur containing amino acids and lysine were most limiting nutritional value of protein in LPC's despite the season of the year when they were produced. There was also a slightly lower level of isoleucine and threonine in LPC's as compared to FAO-WHO protein standard. Total tryptophan however, even in summer, was in concentration considered by FAO-WHO (1973) as nutritionally sufficient.

Limitation in nutritional value of LPC protein due to sulphur containing amino acids and lysine was confirmed in experiments on rats which responded to synthetic DL-methionine and L-lysine supplementation. In summer produced LPC tryptophan appeared to be a third limiting amino acid. Even though the LPC produced in the summer season was supplemented with synthetic methionine and lysine it had still a lower PER value as compared to LPC's produced in spring and autumn which may indicate that despite analytically determined sufficiency of tryptophan as judged by FAO-WHO protein standard, due to processing (heat precipitation) tryptophan became limiting too. This probably was due to lowering in tryptophan availability which has been shown to be as low as 62% in summer LPC as compared to spring and autumn ones (75 and 79%, respectively). Another explanation could be the inadequacy of tryptophan in daily protein allowance given by FAO-WHO (1973). Protein inadequacy in 1973 FAO-WHO recommendations has been demonstrated by Gorza *et al.* (1977)—the objection which has not been raised in reference to 1965 FAO-WHO (1965) recommendations.

There were five distinctive protein fractions which have been determined by polyacrylamide gel electrophoresis in herbage juices extracted from mixed pasture herbage, despite the season when herbage was harvested for processing.

Free and Satterlee (1975) studying the biochemical properties of alfalfa protein concentrate using polyacrylamide gel electrophoresis indicated seven proteins in chloroplast-free juice and six in dialyzed one. This has not been confirmed in the results obtained in this study which can be due to difference in the plant material (clover and perennial grass mixture instead of alfalfa monoculture) since protein fractions distribution is different in the juices of the various plants. Electrophoretic studies indicate a substantial difference in protein fractions between perennial grasses and legumes (Ostrowski—unpublished data).

It has been shown previously (Ostrowski 1979) that fractions 4 and 5 can be identified as low molecular weight proteins (below 2×10^4 MW) which were similar to proteins separated from herbage juice as so called cytoplasmic protein fraction of high nutritional quality—suitable for direct human consumption. Since in LPC recovered from summer grown herbage there was a substantially smaller participation of high nutritional quality protein fractions 4 and 5, it is reasonable to suppose that the overall quality of unfractionated summer LPC should be lower than LPCs recovered from spring and autumn grown pasture. The results obtained in this study indicate that this is so, showing also a satisfactory agreement between analytical results (amino acid concentration and their availability) biological test (PER on rats) and biochemical characteristic of protein (protein fractions). The question still remains however, whether differences in protein quantity and quality may be ascribed purely to seasonal variation in climatic terms, or rather to constant changes in the proportions of protein fractions which can be separated from mixed pasture sward of different botanical composition in various regrowth stages—factors which are related and affected by seasons of the year. This needs further studies.

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LOSSES IN CONVERTING BEEF ANIMALS TO FRESH MEAT PRODUCTS

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ABSTRACT

Losses in converting live beef animals to fresh beef cuts are reviewed. Pre- and post-slaughter condemnations were calculated to account for the major losses amounting to over 59 million lb of carcass beef and 66 million lb of liver annually. The major causes of carcass condemnations were inflammatory diseases (pneumonia), neoplasms (cancer), septic conditions (abscesses) and degenerative conditions (emaciation), accounting for over 88% of total carcass condemnations. On the other hand, carcass condemnations from infectious diseases, parasitic diseases and from residues (drugs and pesticides) amounted to only 1.7, 0.3 and 0.1% of the total condemnations, respectively. In addition, some 4% of all carcasses lost a major part to condemnation. Other major losses included blood and shrinkage (moisture losses) during chilling and holding. All losses are discussed and procedures for minimizing them are suggested.

INTRODUCTION

The losses occurring in conversion of beef animals to fresh meat products can be divided into two types: (1) losses due to condemnations of the carcass or any of its parts; and (2) losses during slaughtering of the animal and in conversion of the carcass to meat products. The former type of losses occur during inspection of the carcass for wholesomeness. The latter kind of losses are encountered during slaughter, chilling and cutting up or boning out of the carcass.

Most of the losses considered are not a complete waste, but result in a decrease in value of the product. In other words, most of the products are not without value but are greatly reduced in value. For example, condemned carcasses are not approved for human food, but can be utilized in other products, such as tankage or in some cases for pet foods. Thus, it should be recognized that the term losses is relative and does not neces-

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sarily imply that the product is discarded without any return. On the other hand, the losses may be completely wasted without any return as is the case where the blood is washed down the drain without any attempt at reclamation. Thus, losses discussed here may range from completely wasting the products to a reduction in value of only a minor amount.

Little information is available on the magnitude of such losses. Thus, the present review was undertaken to point out the amount of losses and to suggest ways by which they can be reduced.

METHODS

The data used herein were obtained from USDA (1975) studies and from unpublished observations and data available in our laboratory. Since the USDA (1975) data on condemnations are given as the number of animals condemned, a dressing percentage of 55% (unpublished observations) was used to calculate carcass weight condemnations. Blood losses were calculated on the assumption that they comprise an average of 3.4% of live weight (Gnaedinger 1962). Shrinkage during chilling and upon holding are based upon personal observations and unpublished records available in our laboratory.

RESULTS AND DISCUSSION

Condemnations

Meat inspection data show that 1 out of every 350 animals slaughtered is condemned (USDA 1975). This amounted to 107,471 cattle or 59,109,000 lb of beef on the assumption that the average slaughter weight was 1,000 lb and the dressing percentage averaged 55%. In addition, some 4,395,693 carcasses were retained at slaughter but were later passed for food.

The causes of condemnations (USDA 1975) are as follows in order of their importance and the number of carcasses condemned for each, with the major reason for condemnation in parenthesis: (1) inflammatory diseases (pneumonia)—31,188; (2) neoplasms (cancer)—28,211; (3) septic conditions (abscesses)—22,326; (4) degenerative conditions (emaciation)—13,596; (5) other causes (injuries and bruises)—8,963; (6) infectious diseases (actinomyocosis)—1,779; (7) pigmentary conditions—556; (8) parasitic diseases—356; (9) and residues (drugs)—138. It is of interest to note that most of these causes are probably not a threat to human health but are generally based on aesthetic considerations. Another point

of more than casual interest is that residues from drugs and pesticides are not a major cause of condemnation, which is contrary to publicity disseminated by the media.

Another point that needs to be mentioned is the fact that condemned beef carcasses and parts are utilized for tankage or some parts may be used for pet foods. Nevertheless, beef carcass condemnations represent a major loss both in terms of food resources and economics. Although a portion of the carcasses and viscera is retained and later passed for human consumption, usage may be subjected to restricted products and result in a reduction of value. Furthermore, there is some reduction of efficiency in operations due to the necessary movement of the carcasses into the retained category.

In addition to entire carcass condemnations, other major losses also occur through condemnation of some part of the carcass. For example, 4,395,693 carcasses or 1 in every 8 carcasses required some trimming (USDA 1975). This means that about 12% of all carcasses require some trimming, with the amount varying from a small amount to major trimming. The latter can result in a major reduction in value not only due to the amount of meat removed but also as a consequence of reduction in the value of remaining parts of the carcass. Furthermore, the labor involved in trimming and in extra handling of the carcasses results in additional economic loss.

Major portions of the carcass, such as the round, loin or chuck, were condemned, from some 1,513,730 carcasses, or 1 out of every 24 carcasses lost a major part (USDA 1975). This means that some 4% of all carcasses lost a major portion or cut due to condemnation.

In addition, 6,654,544 beef livers were condemned (USDA 1975). This means 1 in 5 livers suffered condemnation or 20% were condemned. This amounted to 66,545,440 lb of liver. The condemnations of livers can largely be avoided by proper management and treatment of the live animals.

Many of the condemnations of carcasses and of parts can also be eliminated by proper management and handling of the live animals. The trimming of carcasses is often due to bruising, which results from careless handling, or poorly designed pens and chutes. Most of such losses are avoidable.

Losses in Slaughtering

Blood. On bleeding of beef cattle, the loss of blood is readily apparent. Dilution studies by various techniques have shown that blood volume amounts to 6 to 8% of body weight (Dukes 1943). The amount of blood lost

during the bleeding operation usually comprises about 3.4% of total body weight, although there is variation from animal to animal (Gnaedinger 1962). This means that about half of the blood remains in the carcass and viscera. Warriss (1978) has recently shown that the catecholamines produced in response to stress prior to death cause vaso-constriction and increase the amount of blood removed on exsanguination. On the other hand, anesthetization or other factors causing relaxation increased the amount of residual blood in the meat. Thus, one can alter blood retention, but probably it is not changed appreciably by most slaughter methods.

A 1,000 lb cattle will lose about 34 lb of blood. If the blood is dried, it will yield 3 to 5 lb for either human food or animal feed. With strict pollution laws and efforts to prevent environmental contamination, most blood should be reclaimed. However, it is difficult to obtain good data on the reclamation of the blood. Information obtained in Michigan would suggest that there is little effort to conserve this important resource.Most of the blood being saved is being utilized in animal foods, although the technology is available to produce human food from blood (Tybor *et al.* 1973; 1975; Satterlee *et al* 1973; Crenwelge *et al.* 1974).

Other Losses on Dressing. "Disassembling" of the beef carcass during the dressing operation results in removal of a number of parts with a reduction in weight. The hide reduced live weight by 7–10% (unpublished data). Removal of the variety meats (liver, tongue, heart, kidneys, sweetbreads, brains and oxtail) causes a further reduction of 3.75% of live weight (unpublished data). Edible fat makes up 4–12% of live weight, whereas, inedible fat, bone and meat scraps comprises 17–18% (unpublished data). As already mentioned, blood accounts for 3–5% (Gnaedinger 1962) while the contents of the digestive tract make up 10–15% of live weight (unpublished data). Although most of these products are utilized either for producing tankage or other products, there are some products that can be upgraded. Swingler and Lawrie (1978) and Swingler *et al.* (1978) have recently shown that the proteins from blood plasma, lungs and the rumen can be utilized to produce protein fibers suitable for human consumption. Pearson (1972) suggested that techniques are available so that most by-products can be upgraded into foods for man.

Carcass Yields. Table 1 gives the estimated carcass yields or dressing percentages by carcass grades (unpublished data). There is a decline in carcass yield as grade decreases, primarily due to the decrease related to dressing percentage. Thus, carcass yields vary from a high of about 65% for Prime and Choice grade cattle to 40–50% for U.S. Cutter and Canner grade cattle (unpublished data). It is emphasized that strictly speaking the parts removed during the dressing operation are not necessarily losses since most of them are of economic value as has already been pointed out herein.

Table 1. Carcass yields (dressing percentages) for cattle of different U.S. carcass grades[1]

	% yield
Prime	61–65
Choice	59–63
Good	57–60
Standard and Commercial	53–54
Utility	50–54
Cutter and Canner	40–50

[1]$\text{Yield} = \frac{\text{Cold carcass weight}}{\text{Slaughter weight}} \times 100$

Shrinkage During Chilling and Holding

The weight lost during cooling and subsequent holding at cooler temperatures amounts to about 1.5 to 2.0% during the first 24 h of chilling (unpublished data). During the second 24 h of holding, weight losses comprise about 0.5%, while subsequent storage or holding near freezing for up to 7 days results in a loss of about 0.5% (unpublished observation). This means that total losses amount to about 2.0 to 2.5%.

The losses during chilling and subsequent holding are primarily due to evaporation of moisture. However, prolonged cooler storage may discolor the surface and require trimming. Shrinkage losses are of economic importance to slaughters, since they sell less total weight. On the other hand, it is no great disadvantage to the retailer.

There are several ways to decrease shrinkage during chilling and holding. Turbo-chill was advocated as a means of reducing chill losses, but is not in common use. It has been estimated that Turbo-chill reduces moisture losses during chilling to 0.2–0.5% (unpublished observations). The method uses a chill tunnel well below freezing with high humidity forced air being utilized to reduce carcass temperatures rapidly. The original high cost plus problems from cold shortening have both contributed to the declining popularity of this procedure.

The most recent innovation to be used for reducing chill shrinkage and also to reduce microbial contamination is the chlorine spray, which is patented by Hansen *et al.* (1973). The procedure uses a cold chlorine spray at certain intervals of time to speed up chilling, reduce shrink and stop microbial proliferation. Similar procedures utilize a combination of chlorine and salt in the spray. It is estimated that this process reduces shrinkage during chilling to 0.2–0.6% (unpublished data). Economically this procedure appears to be attractive.

Another procedure for minimizing losses is hot processing, which also should minimize energy costs of processing. It is estimated that hot processing will decrease shrinkage and maximize yields. Estimates suggest

hot processing will hold shrinkage to 0.5–0.75% (unpublished observations), or will decrease losses by two-thirds to three-fourths. This appears to be an attractive procedure for maximizing carcass yields through reducing shrinkage.

Mechanically Processed Beef Product

The new name for mechanically deboned beef is only now coming into use due to sanctions imposed against the old name. Mechanical meat deboning machines can remove large quantities of meat from hand deboned parts. Field (1976) concluded that 30% more meat could be reclaimed per unit of raw material by using mechanical deboning. This would amount to 14.5 lb per beef carcass and result in reclaiming some 497,500,000 lb more meat from beef carcasses annually (Goldstrand 1975). At a value of 60¢/lb this would amount to an added value of $396,500,000 annually.

Thus the use of mechanically deboned beef represents a new development that adds to the efficiency of processing.

CONCLUSIONS

Condemnations and the removal of parts of the animal during slaughtering and shrinkage during holding represent the major losses in slaughtering and processing of beef carcasses. Both types of losses are important to the industry. Some procedures for decreasing such losses are discussed and presented herein.

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EFFECT OF METAL SALTS AND ANTIOXIDANTS ON THE OXIDATION OF FISH LIPIDS DURING STORAGE UNDER THE CONDITIONS OF LOW AND INTERMEDIATE MOISTURES

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ABSTRACT

Cu^{++}, Fe^{+++} and hemin were added to a mixture of mackerel oil and egg albumin, and the pro-oxidative properties of the mixtures were determined at 20°C during storage of water activities (a_w) 0, 0.32 and 0.75, respectively. The pro-oxidant effect of Fe^{+++} or hemin was surpassed by the antioxidant effect of water. Cu^{++} accelerated the oxidation at the highest a_w (0.75), and this was shown by the existence of a critical a_w surpassing the antioxidative action of water.

Antioxidant effect of ethylene diamine tetraacetic acid (EDTA) was slightly observed only in the mixture of Cu^{++} at the highest a_w. α-Tocopherol and butylated hydroxyanisole (BHA) were effective against the oxidation caused by hemin. BHA was only effective as an antioxidant for the Cu^{++} induced oxidation.

INTRODUCTION

It has been well-known that the inclusion of lipids with higher unsaturated fatty acids in dried fish products rapidly cause oxidative deterioration. The effect of humidity on metal-catalyzed lipid oxidation has been investigated by many workers using various model systems. Co^{++} catalyzed the oxidation of the lipid in the systems comprising the methyl linoleate and cellulose powder under dried and intermediate humidified conditions (Labuza *et al.* 1966, 1969, 1971; Labuza and Chou 1974), but did not affect the higher humidity condition, a_w = 0.98 (Labuza *et al.* 1969; Tjhio *et al.* 1969). El-Zeany (1974) reported that Cu^{++} or Fe^{+++} did not accelerate lipid oxidation in the dry state in a model system comprising polyunsaturated fatty acid methyl esters derived from cod liver oil and albumin. These investigations obviously suggest that the effects of metal salts on lipid oxidation are significantly influenced by the state

and amount of water in low moisture foods. The present study was undertaken in order to explore, in a model system, the effects of metals on the lipid oxidation under the conditions of low to intermediate humidities. Metals tested were Cu^{++}, Fe^{+++} and hemin; the former two are deemed to be unavoidable contaminating metals during fish processing, while the latter is a common component in fish flesh. This paper reports, in addition, the influences of butylated hydroxyanisole (BHA), α-tocopherol and ethylene diamine tetraacetic acid (EDTA) on the metal induced oxidation under humidification conditions.

MATERIALS AND METHODS

Mackerel oil was supplied by the Central Research Institute of Nippon Kagaku Shiryo Co. Ltd., Hakodate. Egg albumin was purchased from Wako Pure Chemicals. All other chemicals used were reagent grade.

Model Mixtures

An ether solution of mackerel oil was added to egg albumin, and a final mixture of three parts of mackerel oil to seven parts of the albumin (w/w) was prepared following evaporation of the ether by streaming with nitrogen gas. The pro-oxidant systems consisted of 10 ppm of either Cu^{++}, Fe^{+++} or hemin based on the amount of the oil used. The antioxidants used were 200 ppm of α-tocopherol, BHA or EDTA added to the pro-oxidant systems. Five grams of each of the mixtures were transferred into separate 100-ml Erlenmyer flasks. The samples were humidified in vacuum desiccators over a salt solution and adjusted to desired water activities ($a_w \approx 0$, 0.32 and 0.75) at 20°C. This was done by evacuating the desiccators and allowing the samples to equilibrate for one week. After equilibration, the Erlenmyer flasks containing the mixtures were sealed with a rubber stopper and placed in a chamber at 20°C to measure the oxygen absorption.

Oxygen Absorption

Oxygen and nitrogen contents in the head space of the Erlenmyer flasks were measured by using a Hitachi 164 gas-chromatograph equipped with a thermal conductivity detector, on a 3 mm × 2 m stainless steel column packed with Molecular Sieve 5A, at 70°C, and helium flow rate 50 ml/min. The oxygen absorbed in the mixture was calculated from the formula:

$$\text{Absorbed } O_2\ (\%) = 100(1 - A_t/A_0)$$

where A_0 and A_t are the ratios of O_2 peak areas at zero time and time t, respectively, to the sums of the N_2 and O_2 peak areas in gas-chromatograms.

RESULTS AND DISCUSSION

The effects of humidification ($a_w \approx 0$, 0.32 and 0.75) on the catalytic rates of oxidation induced by metal ions in the model mixtures are shown in Fig. 1. The time required to reach the 2% oxidized level is shown in Table 1. At 2% oxidation, the samples would be entering the bimolecular oxidation period as shown in Fig. 2. Maloney *et al.* (1966) and Labuza *et al.* (1969) studied the kinetics of the effects of water on lipid oxidation using model mixtures, and demonstrated the value of special kinetic plots. Figure 2 shows the plot of the square root of oxygen absorbed in

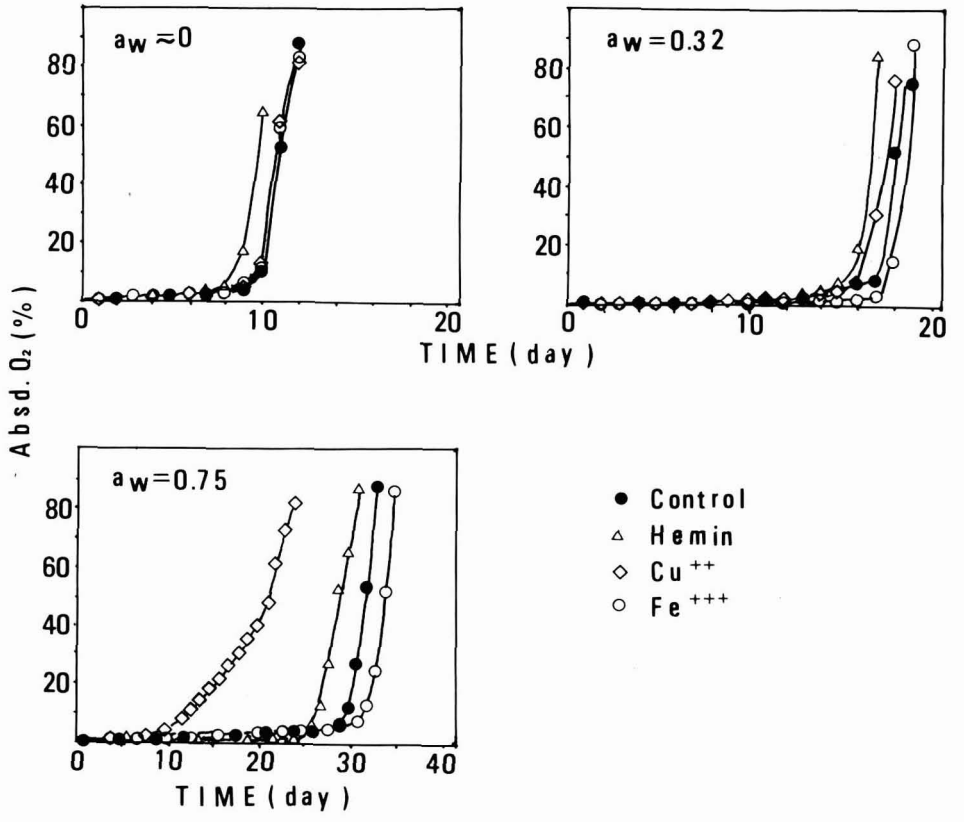

FIG. 1. OXYGEN ABSORPTION OF MODEL SYSTEM AS A FUNCTION OF a_w AT 20°C

Table 1. Effect of humidification on time required to reach 2% oxidation in mackerel oil-egg albumin model system at 20°C

	Water Activity		
	0	0.32	0.75
	Time (day)	Time (day)	Time (day)
Control	9.9	16.8	29.1
Fe^{+++}	9.5	18.0	30.3
Cu^{++}	9.7	16.2	11.4
Hemin	8.4	15.0	25.2

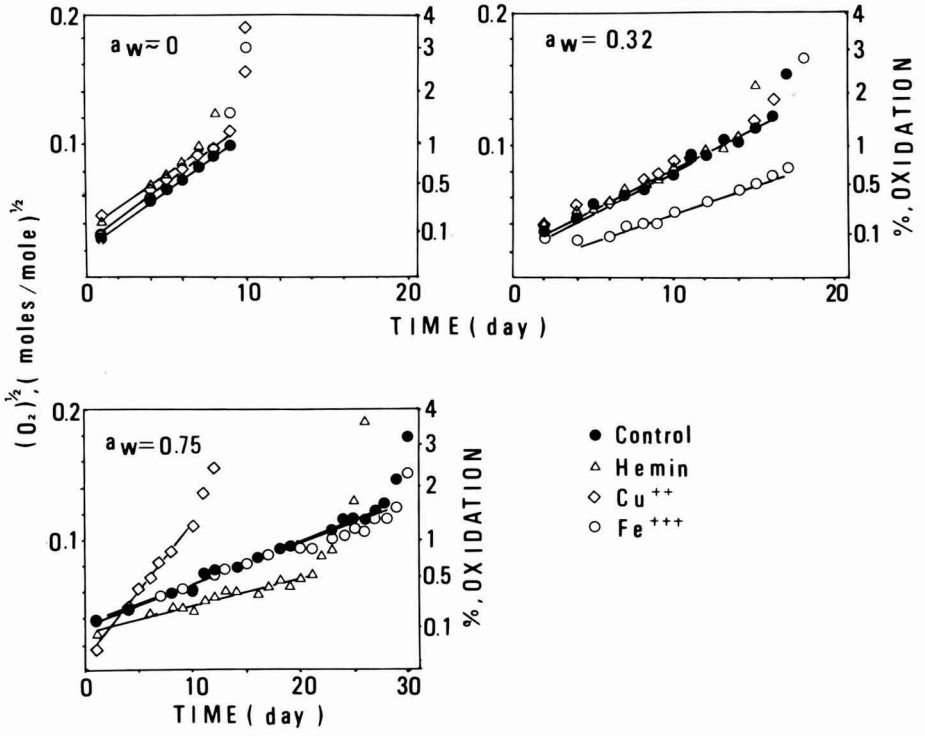

FIG. 2. KINETIC PLOT FOR THE MONOMOLECULAR RATE PERIOD IN MODEL SYSTEM AS A FUNCTION OF a_w AT 20°C

moles of oxygen, per mole of lipid against the storage time. The plots indicate a straight line up to 1–2% of the oxidation level and it is assumed that the initial stage of the oxidation in this region is caused by monomolecular decomposition reactions of hydroperoxides. In general, the rate constants of the reactions [(O_2 moles/lipid mole)$^{1/2}$ · day^{-1}] decreased as a_w increased, and were about 80–90 in the mixtures at $a_w \approx 0$, 40–60 at $a_w = 0.32$ and 20–30 at $a_w = 0.75$, except that the rate constant was higher for the Cu^{++} added mixture (about 110) at $a_w = 0.75$. In these results, the induction periods were prolonged in proportion to the a_w (0 to 0.75) in the cases of the control, and mixtures with Fe^{+++}, and hemin; whereas in the case of added Cu^{++} the reverse was observed between $a_w = 0.32$ and 0.75. This fact suggested that a critical water

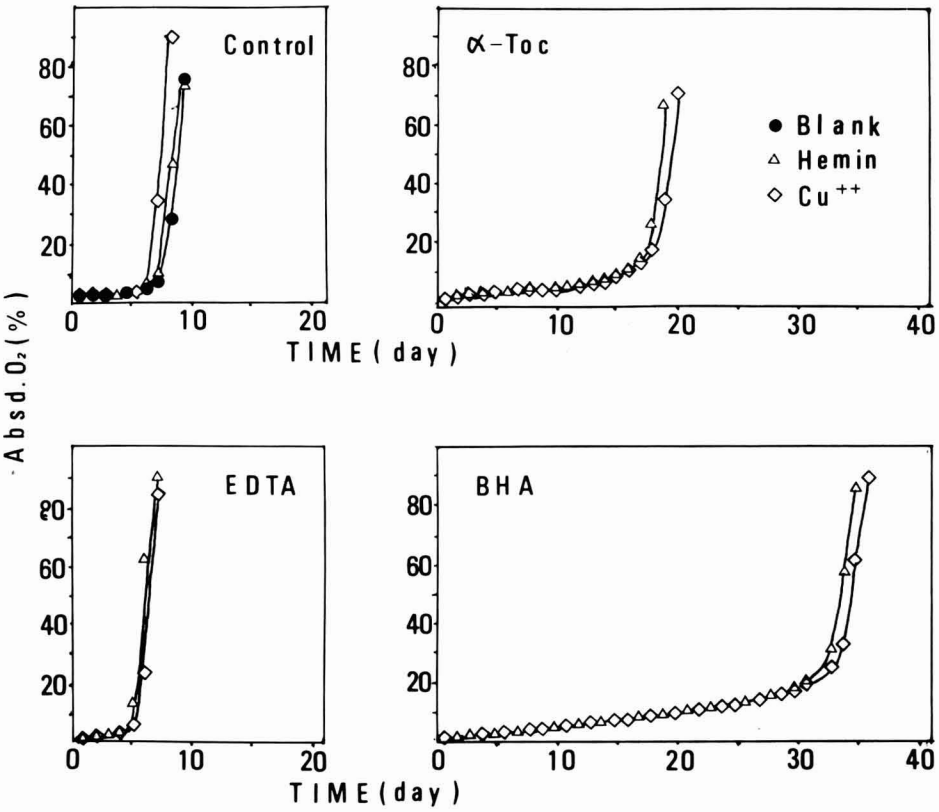

FIG. 3. EFFECT OF ANTIOXIDANT AND CHELATING AGENT ON OXYGEN ABSORPTION OF MODEL SYSTEM AT $a_w \approx 0$ (20°C)

activity existed in the a_w region between 0.32 and 0.75. The appearance of the antioxidant effect of water probably is attributable to dilution of the reactants and catalysts (Labuza *et al.* 1971). This is contrary to the result in Cu^{++} added but it may be explained by the lower solubility of Cu salt ($CuCl_2$) than Fe salt ($FeCl_3$) and hemin.

Figures 3 through 5 show the effects of antioxidants and chelating agent on oxygen absorption of the model mixtures especially constituted Cu^{++} or hemin, as a function of a_w. The results were obtained by using a different batch of lipid from the experiments without those agents. In the case of added hemin, oxygen absorption rates tended to decrease with increasing a_w (Fig. 1 and 2); the tendencies were extensibly maintained

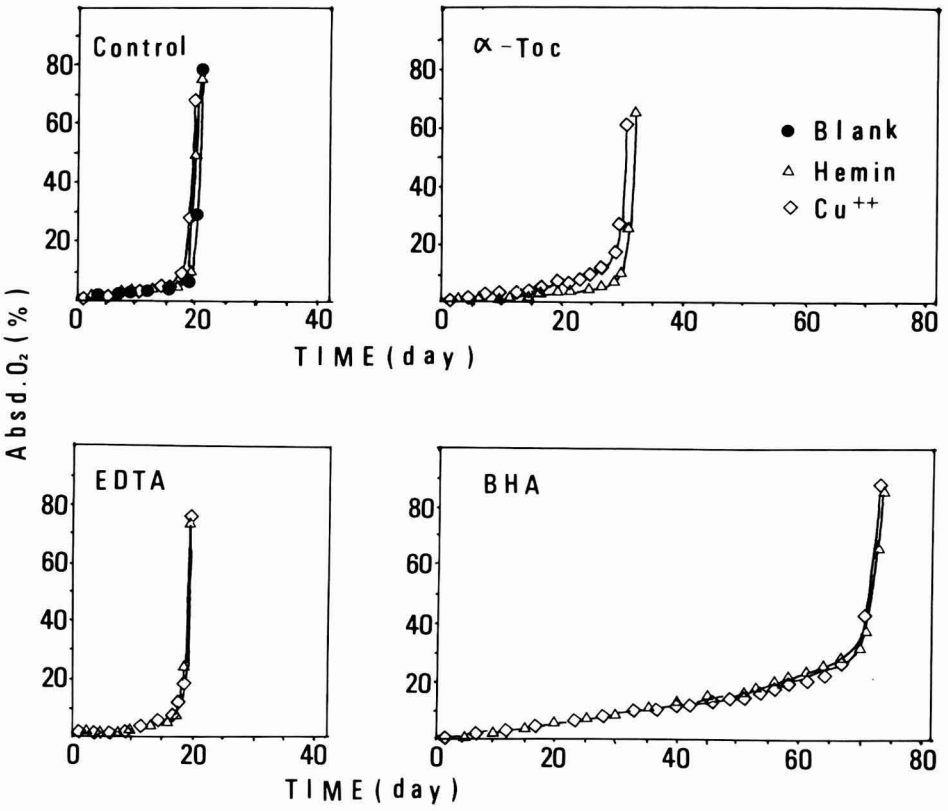

FIG. 4. EFFECT OF ANTIOXIDANT AND CHELATING AGENT ON OXYGEN ABSORPTION OF MODEL SYSTEM AT a_w = 0.32 (20°C)

by the existence of α-tocopherol in particular at $a_w = 0.75$ in the early stage of the initial oxidation (Table 2). The oxygen absorption in the hemin mixture, however, was characteristically accelerated above the induction period. Although ethylene diamine tetraacetic acid (EDTA) scarcely had any effect on the actions of Cu^{++} and hemin under the conditions in this investigation except in the case of the Cu^{++} added mixture at $a_w = 0.75$, α-tocopherol and butylated hydroxyanisole (BHA) acted synergetically with the antioxidative action of water. Particularly, it was remarked that BHA inhibited the Cu^{++} action as characterized by the existence of a critical a_w in the intermediate region surpassing the antioxidative action of water.

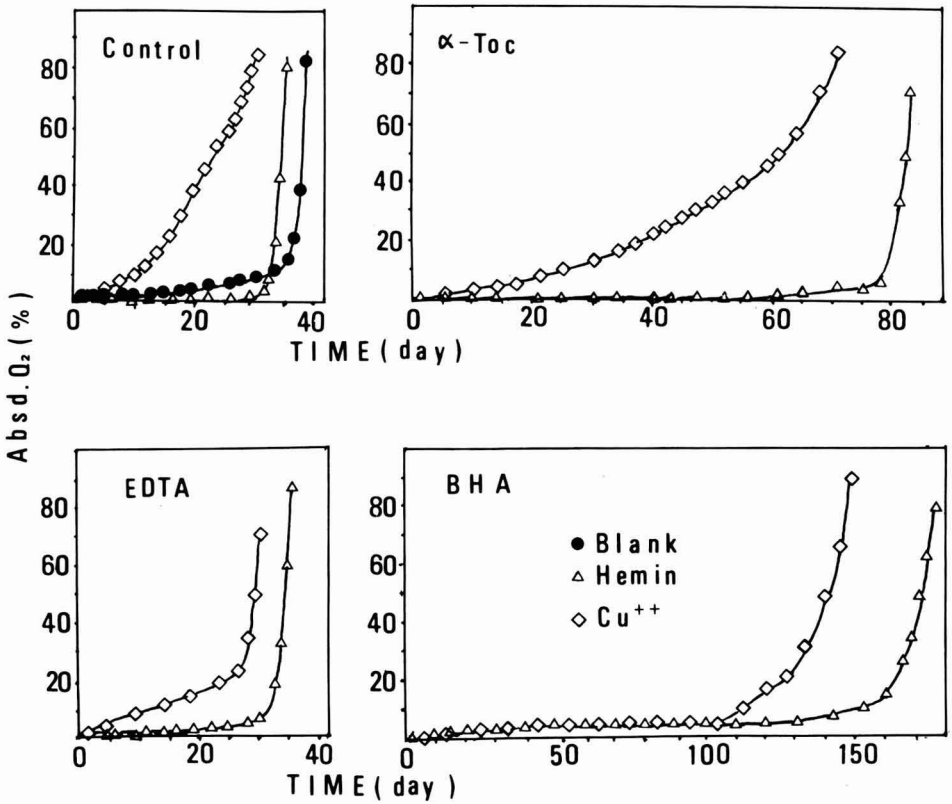

FIG. 5. EFFECT OF ANTIOXIDANT AND CHELATING AGENT ON OXYGEN ABSORPTION OF MODEL SYSTEM AT $a_w = 0.75$ (20°C)

Table 2. Effect of antioxidant and chelating agent on time required to reach 1% and 2.5% oxidations as a function of water activity in mackerel oil-egg albumin model system at 20°C

		Time to Reach 1% Oxidized, (day)			Time to Reach 2.5% Oxidized, (day)		
		Water Activity			Water Activity		
		0	0.32	0.75	0	0.32	0.75
Control	Cu^{++}	5.5	13.8	5.0	6.4	18.0	10.1
	Hemin	6.0	13.9	32.2	7.0	18.8	33.3
EDTA	Cu^{++}	5.6	13.7	4.1	6.5	17.8	12.2
	Hemin	5.2	14.1	19.4	5.9	18.3	32.1
α-Tocopherol	Cu^{++}	8.6	14.1	13.8	15.6	25.3	31.6
	Hemin	8.9	25.4	71.8	15.0	30.1	79.0
BHA	Cu^{++}	8.3	14.2	22.3	20.4	31.6	110.8
	Hemin	8.5	13.9	22.5	20.4	29.2	150.4

Oil used is a different batch from that in the experiments without antioxidant and chelating agent as shown in Fig. 1 and 2, and Table 1.

ACKNOWLEDGMENT

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BOOK REVIEWS

Effects of Heating on Foodstuffs. Edited by R. J. Priestley. Applied Science Publishers, Rippleside Commercial Estate, Barking, Essex, England.

The title, utilizing the vernacular term "Foodstuffs" hardly does justice to the technical and scientific information given in the book. It might more appropriately be entitled "Effects of Heating on Food or Food Components or Food Ingredients" but not foodstuffs.

The book is well-written, reads reasonably well for a collection of manuscripts by a variety of authors and should make a useful reference book for a food technologist. The text is divided into 12 chapters covering proteins, carbohydrates, pigments, vitamins, meat, poultry, eggs, fish, fruits, vegetables, milk and dairy products and cereals, roots and other starch-based foods.

Each chapter deals with the basic property of the food component, e.g. proteins and component amino acids, and expands into the thermal properties and subsequent effects of heat on the food component.

This format aids the reader in recalling basic properties and assists in understanding the influence of thermal processing on food materials.

The chapters concerned with food commodities are developed in much the same manner. For example, the chapter on poultry meat initiates with a discussion of the composition of chicken and turkey, deals with methods of heating and concludes with a discussion on the effect of heating on the quality of the poultry meat.

It is difficult for this reviewer to envision a course in food technology where this book could be used as a text. One or several chapters may be useful as reference material in a course concerned with the thermal processing of food. For those involved with heating of food, this book would be an excellent reference.

EDMUND A. ZOTTOLA

Sugar: Science and Technology. Edited by G.G. Birch and K.J. Parker. 1979. $67.00. Applied Science Publishers, Rippleside Commercial Estate, Barking, Essex, England.

This book is a collection of twenty-two papers presented at a Symposium held at the University of Reading in 1978. The topics include the

Journal of Food Processing and Preservation 3 (1979) 259–261.

history, economics, refining, and technology of sucrose; basic sucrose chemistry; glucose syrups; fructose; xylitol; sugar analysis; various food applications of sugars; sweetness perception; and the relationship of sugar and health. While the emphasis of the book is directed toward sucrose, attention is also given to other sugars and sugar alcohols. As the title implies, the Symposium proceedings present a balance of the scientific and technological aspects of sugar written by people from industry and universities. In some chapters recent research findings, such as sweetness intensity, are presented. In the case of refining, a complete description of sugar processing technology is given. Several chapters reflect the concerns and controversies surrounding the influence of sugar consumption on metabolism and the role of sugar in dental caries. Most of the information appears current and consideration is often given to discussing the latest thinking and future developments on a number of sugar-related topics.

The book is well-edited and technical errors are minimal. Most presentations include extensive reference lists, which should be useful for readers in need of further information. An index also contributes to the value of the book as a reference. A weakness of the book is that there are several poorly organized or poorly written chapters that differ in quality from the majority of the sections which are well-written. As is common in symposium proceedings, there is some overlap between chapters written by different authors but this repetition tends to reinforce certain concepts and does not detract from the book.

This book should be useful to food scientists and food technologists because it contains basic technical information on sugars, describes industrial processing techniques, discusses varied applications of sugars for food and nonfood uses, and includes some current issues regarding sugar consumption.

J. J. WARTHESON

Nutritional and Safety Aspects of Food Processing. Edited by S. R. Tannenbaum. Published by Marcel Dekker, Inc., New York.

A book with this title promises much and one has great expectations when one sees it. This book does deliver, in part, and does make a valuable contribution and, because of its broad nature, could be used in a graduate level course on current food science problems. However, some of the chapters are quite lacking as compared to others which are in-depth

reviews. The book is divided into twelve chapters written by different authors who are, for the most part, from the Department of Nutrition and Food Science at MIT. The book starts with a short introduction and then covers nutrient requirements, the chemistry of vitamin losses in processing and storage, a review of the effect of processing on lipids, minerals in foods (a very short and very weak chapter), the effects of processing on proteins and amino acids (an excellent review), the technology of fortification, prediction of nutrient loss (a very good review), antinutritional and accidental toxic substances in foods, an excellent review of the use and problems of agricultural chemicals in foods, preservative action and immunological aspects of foods (very short and weak).

As noted, some chapters are excellent reviews and these make the book worth purchasing. The problem lies with the weak chapters where important facts were left out. For example, nothing was mentioned about use of the HPLC method for vitamin analysis, nor was there mention of iodophors as being a source of iodine and a creator of problems. In the chapter on presence of toxic substances where microbial problems were covered, no mention of *perfringens* was made, nor was there any real discussion with respect to processing effects on microbial toxin and growth. These are counter balanced, however, by excellent discussions on how the RDA is set; on toxicity of frying oils; on protein and amino acid changes in processing; on fortification problems for dehydrated foods; and on processing effects on agricultural chemicals. These make the book worth owning as a reference.

THEODORE P. LABUZA

JOURNALS AND BOOKS IN FOOD SCIENCE AND NUTRITION

JOURNAL OF FOOD BIOCHEMISTRY — Herbert O. Hultin
Norman F. Haard and John R. Whitaker

JOURNAL OF FOOD PROCESS ENGINEERING —
Dennis R. Heldman

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SECOND EDITION — James F. Price and B. S. Schweigert

GUIDE FOR AUTHORS

Typewritten manuscripts in triplicate should be submitted to the editorial office. The typing should be double-spaced throughout with one-inch margins on all sides.

Page one should contain: the title, which should be concise and informative; the complete name(s) of the author(s); affiliation of the author(s); a running title of 40 characters or less; and the name and mail address to whom correspondence should be sent.

Page two should contain an abstract of not more than 150 words. This abstract should be intelligible by itself.

The main text should begin on page three and will ordinarily have the following arrangement:

Introduction: This should be brief and state the reason for the work in relation to the field. It should indicate what new contribution is made by the work described.

Materials and Methods: Enough information should be provided to allow other investigators to repeat the work. Avoid repeating the details of procedures which have already been published elsewhere.

Results: The results should be presented as concisely as possible. Do not use tables *and* figures for presentation of the same data.

Discussion: The discussion section should be used for the interpretation of results. The results should not be repeated.

In some cases it might be desirable to combine results and discussion sections.

References: References should be given in the text by the surname of the authors and the year. *Et al.* should be used in the text when there are more than two authors. All authors should be given in the References section. In the Reference section the references should be listed alphabetically. See below for style to be used.

DEWALD, B., DULANEY, J. T. and TOUSTER, O. 1974. Solubilization and polyacrylamide gel electrophoresis of membrane enzymes with detergents. In *Methods in Enzymology*, Vol. xxxii, (S. Fleischer and L. Packer, eds.) pp. 82–91, Academic Press, New York.

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ZABORSKY, O. 1973. *Immobilized Enzymes*, pp. 28–46, CRC Press, Cleveland, Ohio.

Journal abbreviations should follow those used in *Chemical Abstracts*. Responsibility for the accuracy of citations rests entirely with the author(s). References to papers in press should indicate the name of the journal and should only be used for papers that have been accepted for publication. Submitted papers should be referred to by such terms as "unpublished observations" or "private communication." However, these last should be used only when absolutely necessary.

Tables should be numbered consecutively with Arabic numerals. The title of the table should appear as below:

Table 1. Activity of potato acyl-hydrolases on neutral lipids, galactolipids, and phospholipids

Description of experimental work or explanation of symbols should go below the table proper.

Figures should be listed in order in the text using Arabic numbers. Figure legends should be typed on a separate page. Figures and tables should be intelligible without reference to the text. Authors should indicate where the tables and figures should be placed in the text. Photographs must be supplied as glossy black and white prints. Line diagrams should be drawn with black waterproof ink on white paper or board. The lettering should be of such a size that it is easily legible after reduction. Each diagram and photograph should be clearly labeled on the reverse side with the name(s) of author(s), and title of paper. When not obvious, each photograph and diagram should be labeled on the back to show the top of the photograph or diagram.

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Standard nomenclature as used in the scientific literature should be followed. Avoid laboratory jargon. If abbreviations or trade names are used, define the material or compound the first time that it is mentioned.

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