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EDITORIAL

As stated in the editorial of the first issue of the new British international journal *Food Chemistry*, "the publication of a new journal has been considered by some people to be of doubtful merit in these days of rising costs . . . ." Their editor however felt that the new journal would provide an outlet for papers which would not find places otherwise.

I can agree with the first statement in part, since we are all faced with rising costs of research personnel, and equipment; libraries are looking to reduce book and journal subscriptions. However, we are facing an information explosion. In a recent National Science Foundation report on scientific and technical articles, they found a 40% increase between 1960 and 1974 from about 106,000 to 151,000 articles published. Scientific and technical book titles increased from about 3,000 in 1960 to 14,000 in 1974, the latter due to more narrow-specific titles in specialized areas of scientific disciplines. From 1972 to 1976 about ten books were published just on proteins and their evaluation in the area of food science and technology.

This increase in scientific information needs an outlet. Books take too long to get into print; I know, having now written three of them and chapters for many more. Scientific journals should exist as a rapid outlet for current research as well as short reviews on exciting topics. A perusal of the many journals in food science and technology shows this to be so. A deeper investigation shows that they are all growing in size and in cost as well.

When I graduated with a B.S. in Food Science in 1962, the *Journal of Food Science* was in a smaller size, and had 617 pages devoted to about 85 articles. By 1966 it had grown to 1,030 pages; by 1970 to a smaller number of pages (876), but of larger size so that the number of articles almost tripled (about 235 articles). From 1971 to 1976 it increased almost every year, when in 1976 it was up to 1,510 pages with almost 370 scientific articles. This is an increase of 60% since 1970. Most likely it will increase by another 20% by the end of 1977. In comparing this to the NSF data, we have seen in the *Journal of Food Science* an increase of 400% in the number of articles. This is a ten times greater increase over the same period. In the same period we have seen the addition of the *Canadian Journal of Food Technology* (Vol. 9, in 1977); *International Journal of Food Chemistry* (Vol. 1, in 1976) as mentioned above; *Journal of Food Technology* (Vol. 12, in 1977); and *Lebensmittelen Wissenschaft und Technologie* (Vol. 10, in 1977). They are growing and certainly have filled a need. *Cereal Chemistry* is now in its 53rd year; the *Journal of Agriculture and Food Chemistry* is now in

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its 24th year; *Food Technology* is beginning its 31st year; while the *Journal of Food Science* is starting Volume 42. The *Journal of Milk and Food Technology* in 1977 will enter its 40th year under its new name of *Journal of Food Protection.*

Statistics like these imply indeed, food science and technology is an active and growing field and thus the journal space will expand to fill the desire to print, to paraphrase a famous saying. We hope that by our choice of an extremely reputable editorial board we can attract excellent, timely and exciting new research.

The idea as stated in our guide for authors is to not be narrow. Here is where I disagree with the editor of the new *Food Chemistry*. I don't feel that their journal will be an outlet for papers that can't find a home. I am sure they could be published elsewhere as well. I hope that those papers submitted to the *Journal of Food Processing and Preservation* could be published elsewhere, since we will cover the broad field of food chemistry, physical chemistry, microbiology, and engineering of foods as related to processing and preservation. What we offer is what we hope will attract good papers. The Journal I feel has a very distinguished review board. This ensures good reviews. We will not charge for pages. We also offer a new outlet for publication in the United States. It should be noted that all of the previous newer journals listed above are foreign journals. This sometimes adds to the problems of publication. We also offer an outlet to expand one's resume. Too often I have seen colleagues criticize peers because they only publish in one journal. With our new series of journals this should at least alleviate part of the problem.

Finally, we must offer something to those who subscribe and read our Journal. Without them we cannot exist, which has been the demise of several narrowly oriented journals in the past (e.g., *Biodynamica*). Our policy is to strive for current viable research articles which will stimulate others and add to the expanding body of scientific knowledge about foods. The Journal will contain both basic as well as applied research to serve our society as a whole. I do not see it as a drain on other publications, but as another step in the exponential growth curve of our field. Just my own experience in the field of water activity of foods from its beginnings as a scientific concept in the early 1960's to today where it is being incorporated in Federal Regulations makes me feel there are more concepts yet undiscovered that will see the same growth. Without publication they will benefit no one. I invite all those involved in the field to join in our endeavor by submitting articles, buying subscriptions, and most importantly reading our issues.

Theodore P. Labuza

THE MECHANISM OF CAKING OF POWDERED ONION

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ABSTRACT

The caking of powdered onion is initiated by bridging of wet surfaces of particles. The forces that develop are sufficient to attract the particles and can cause a humidity shrinkage.

Water absorption is the dominant factor in the caking process. The relative humidity and its history regulate the rate and the pattern of the physical changes that the powder may undergo. Flow conditioners are ineffective as caking inhibitors when moisture absorption is undisturbed. The conditioners can provide a physical barrier that facilitates flow, but cannot provide the type of coverage that protects the powder from water absorption.

INTRODUCTION

Many food powders may undergo physical changes during their storage or handling that result in the loss of flowability and the formation of agglomerates. Though the physical mechanisms which may be involved are of a diverse nature the phenomenon, as a whole, is usually referred to as a caking problem.

Powdered onions, like many other powders made from dehydrated fruits and vegetables, contain a relatively high concentration of water soluble materials and are known for their hygroscopicity. At low moisture content, i.e. up to about 3%, powdered onion is a typical free flowing powder showing low compressibility, low tensile strength and low cohesion (Peleg *et al.* 1973). At higher moisture content, i.e. from about 4% onwards, the material becomes cohesive and may reach levels

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of cohesion that cannot be evaluated quantitatively by methods designed for powders. The moisture level in which powdered onion becomes cohesive and shows agglomeration tendency depends to a great extent on the temperature (Peleg Y. and Mannheim 1969). In the range of 15 to 35°C the caking tendency increases with temperature, a trend that could be expected from the behavior of other powders (Notter *et al.* 1958; Notter *et al.* 1959; Lazar and Morgan 1966).

The most successful method for caking inhibition in hygroscopic food powders is drying the powder to a low moisture content followed by storage in a proper water impermeable package. Additional means like vacuum packaging, in package desiccation (IPD) and refrigerated storage are also effective though in many cases their application is avoided for economic reasons.

An economically feasible method for improving the situation is the application of flow conditioners also called anticaking agents, anti-agglomerants and glidants. These are finely divided powders having a particle size much smaller than that of the host powder. Their chemical composition is very diversified. The main food grade groups are silicates, stearic acid salts, phosphates, and starches. Their main effect as flow conditioners is achieved by providing a physical barrier between the host particles thus reducing the cohesive forces (Peleg and Mannheim 1973). They are also known for their capability of reducing friction internally and cancellation of attractive electrostatic charge (Nash *et al.* 1965). Their presumed role as caking inhibitors by providing a competitive water sorption capacity has been challenged by Irani *et al.* (1961) who showed that no correlation could be found between the conditioners sorption capacity and their effectiveness as caking inhibitors. In a previous report some conditions under which caking of powdered onion could be inhibited were described by Y. Peleg and Mannheim (1969).

In this work the caking phenomenon itself is studied and the potential role of some conditioners is evaluated.

EXPERIMENTAL

Commercial dehydrated onion flakes were ground by a laboratory mill. The powder was sieved and dried in a vacuum oven and sealed in tin cans. The fraction of −60 + 80 mesh was admixed with two different conditioners. One, calcium stearate (BDH-England) as a representative of the stearate group and the second a precipitated aluminum silicate (BDH-England) as a representative of the silicate group. The

concentrations of both conditioners was 1%. The treated, as well as the untreated, samples were left to equilibrate at various relative humidities in vacuum desiccators stored at 25°C. The various relative humidity levels were provided by concentrated sulfuric acid and saturated salt solutions as described by Rockland (1960).

Caking observation was done daily at various conditions including sealed glass containers (about 100 g capacity). These were stored at temperatures of 25, 35 and oscillating temperatures between 25 and 35°C every 12 hours. Caking was determined when there were apparent lumps which could not be broken easily by shaking the container or when the whole powder bed formed one continuous mass that could not flow.

RESULTS AND DISCUSSION

The time until caking of powdered onion at various relative humidities is shown in Fig. 1 for 25°C. At storage conditions of higher than about 40% RH, caking time was inversely related to the relative humidity. Below 40% RH, the powder remained free flowing (for more than six months) regardless of the presence of the conditioners. A similar pattern was found in the samples which were stored in the sealed containers. Those with low initial levels of moisture content maintained their free flowability even without the conditioners and at all the temperature conditions. The samples with high moisture content, caked within a few days. This was regardless of the temperature studied and the presence of the conditioners.

Though the strength of the agglomerates has not been evaluated nor the flowability of the free flowing powder, it is obvious that the major role in the caking process is played by moisture absorption which greatly overpowers any possible effects of the conditioners. The amount of moisture in equilibrium was not influenced by the presence of conditioners as can be seen in Fig. 2. This was expected as the coverage of the surface by the solid particles is insignificant from the sorption point of view. A schematic representation of the situation is shown in Fig. 3. As seen in the figure, the conditioner particles may provide a physical barrier between neighboring particles. The nature of the conditioner, i.e. its composition and shape, may be of the kind that will provide an additional lubrication effect thus reducing the internal friction and facilitating flow. It cannot, however, even at a complete coverage, provide a water impermeable layer or a significant physical coverage of water sorption sites. This implies that the conditioners may

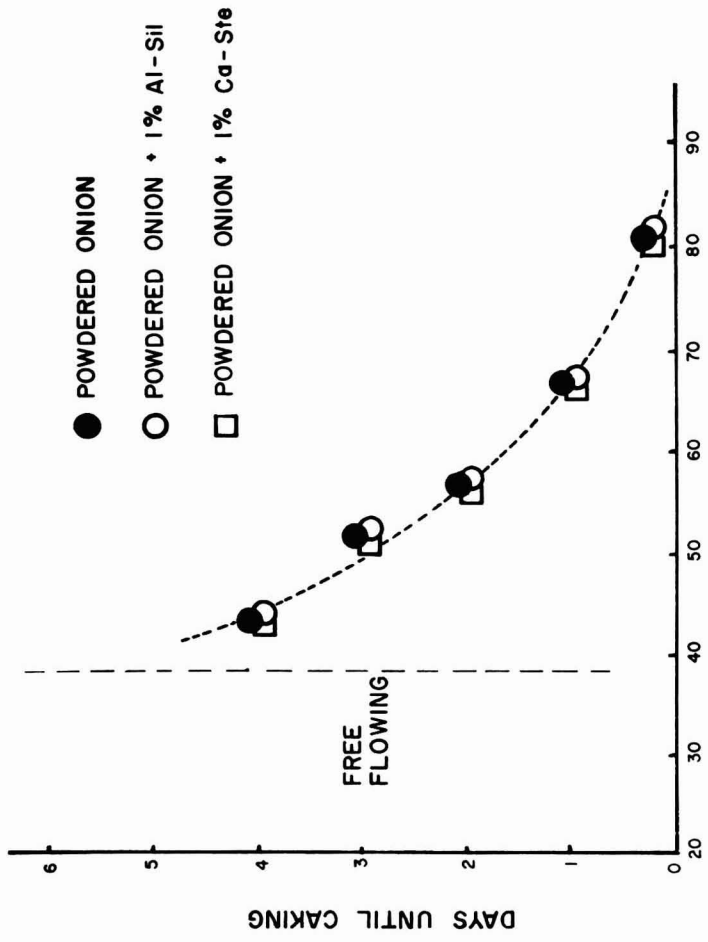

FIG. 1. CAKING RATE OF POWDERED ONION STORED AT VARIOUS RELATIVE HUMIDITIES AT 25°C

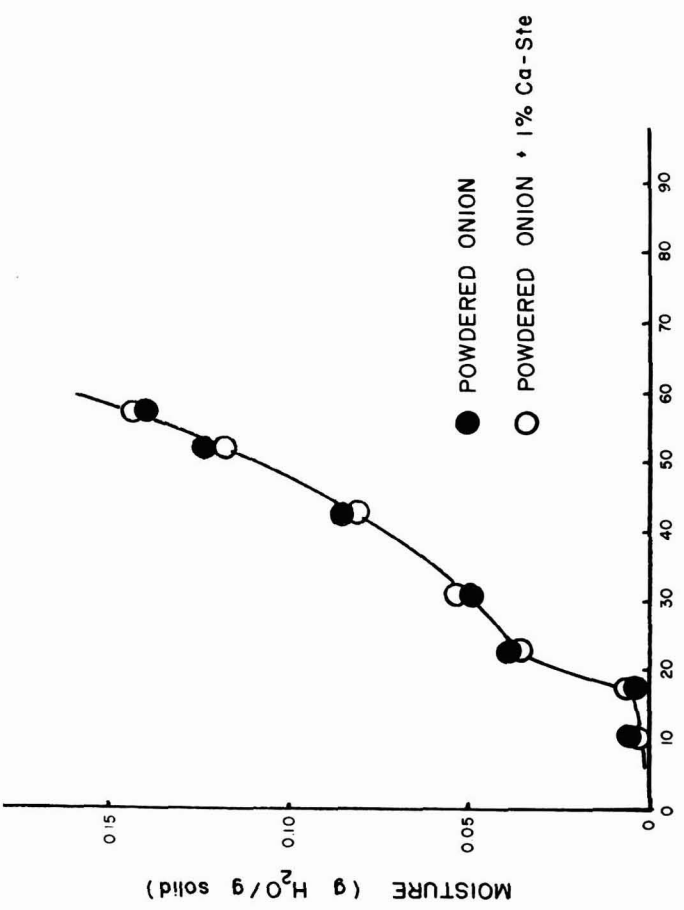

FIG. 2. EQUILIBRIUM MOISTURE ISOTHERM (25°C) OF POWDERED ONION WITH AND WITHOUT A CONDITIONER

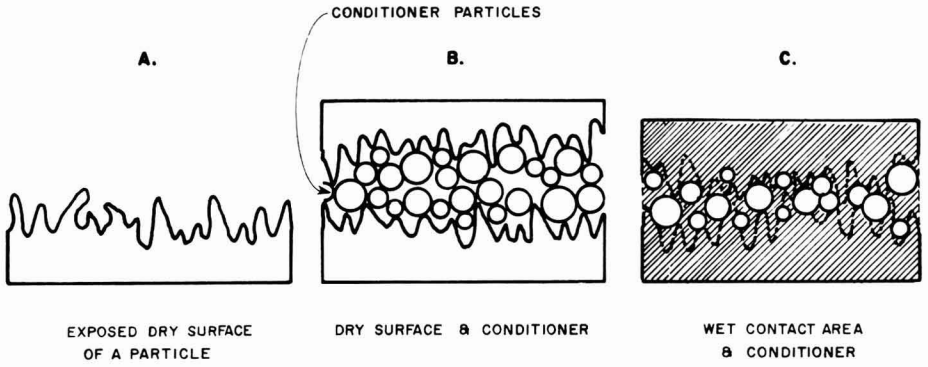

FIG. 3. A SCHEMATIC VIEW OF A PARTICLE SURFACE WITH AND WITHOUT A CONDITIONER

Note that while a conditioner may be a good physical barrier, its coverage of sorptive area is insignificant and it cannot prevent the formation of liquid bridging.

improve the flowability only when the powder is dry. It should be mentioned though, that some limited anticaking capacity of conditioners at high relative humidities cannot be excluded on the basis of the data presented in this work. A situation in which such a possibility may emerge is the case where a treated powder is exposed to a moist atmosphere for a short period only. If the exposure time is short enough, the physical barrier offered by the conditioners may be sufficient to avoid or interfere with the creation of interparticle bridging by the partially moist surfaces. In such cases the interparticle attraction or cohesion may be kept at low levels thus maintaining the flowability of the powder (Peleg and Mannheim 1973).

THE MECHANISM OF AGGLOMERATION

The mechanism of binding of the particles is of the kind usually referred to as "humidity caking." The process is typical to powders that are water soluble or contain water soluble materials (Burak 1966; Pietsch 1969). A schematic view of the process is shown in Fig. 4. When water is absorbed on the surface of the particle the latter becomes sticky. The water may be absorbed from the atmosphere or may condense on the particle due to a temperature drop during storage. The process of moisture migration into both the powder bed and the interior dry parts of the particles may be slow enough that the surface of both the bed and the particles may stay sticky while the central parts

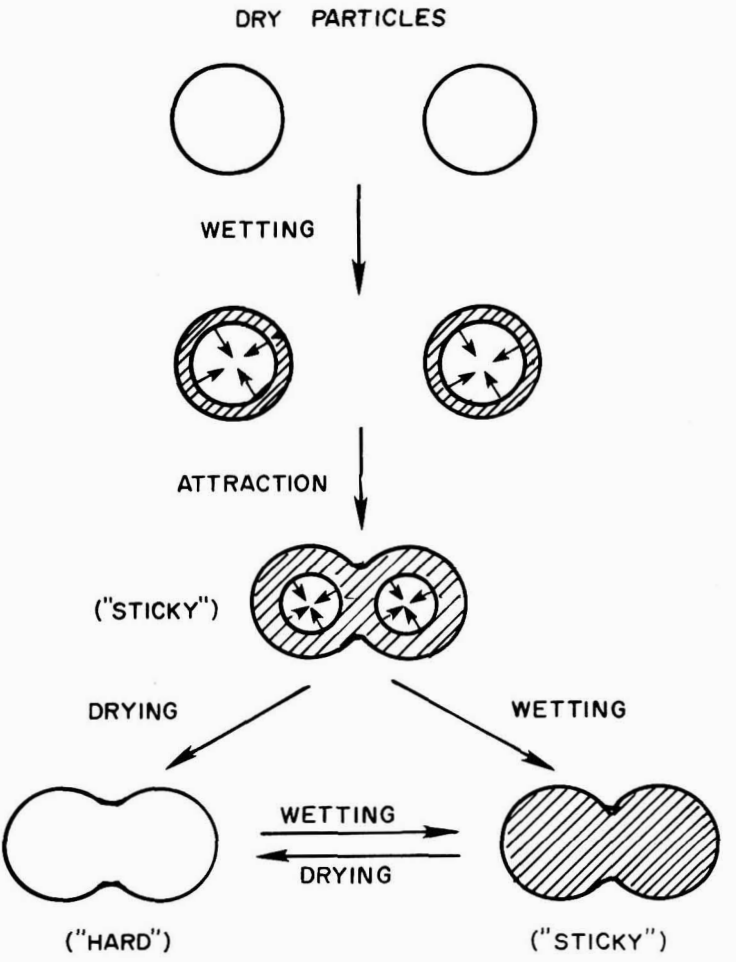

FIG. 4. SCHEMATIC REPRESENTATION OF THE HUMIDITY CAKING MECHANISM OF POWDERED ONION

Note that the wetting and drying as well as the amount of diffusion may be a repeated process varying in extent according to the humidity-temperature history of the powder.

are still dry. The wet surfaces, with moisture being absorbed, may contain a saturated solution of the soluble components of the surface material. The solution can form liquid bridges or a continuous medium, thus attracting the particles together (Rumpf 1961). This stage of attraction is not a hypothetic stage and can be observed in fact. Fig. 5 shows that moisture absorption can result in a considerable shrinkage of powder beds stored at high relative humidities. The latter indicates that the forces which are developed by the liquid layers at the surfaces can cause a movement of particles in the bed to form a closer array.

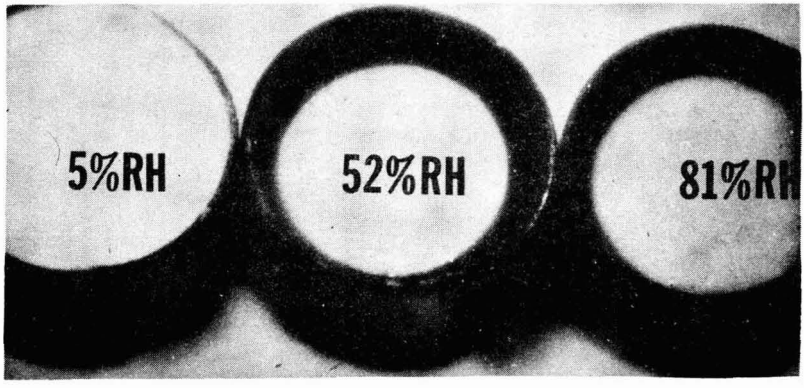

FIG. 5. HUMIDITY SHRINKAGE OF POWDERED ONION AS A FUNCTION OF RELATIVE HUMIDITY

The caking at this stage is characterized by the stickiness of the powder surfaces and may develop in two main directions. If drying occurs at this stage (due to controlled or uncontrolled circumstances), it will cause a resolidification of the liquid bridges thus forming hard, dry lumps. If the moisture absorption is allowed to continue, it will eventually reach the stage when all the mass is rendered wet and sticky and can hardly be considered as a powder.

Under practical conditions, the humidity-temperature history may vary. Additional factors that effect the phenomenon are the selective solubility of the powder chemical components, the surface properties that regulate the water absorption and the water diffusivity within the particles. These also may vary according to the origin of the material and the process history of the powder. The great variability in the factors that play a role in the caking of powdered onion indicates that the phenomenon is by no means a process that follows a uniform pattern.

ACKNOWLEDGMENT

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PROTEIN PRODUCTION BY SUCCESSIVE GROWTH OF *BACILLUS SUBTILIS* AND *LACTOBACILLUS ACIDOPHILUS* ON COMBINED FOOD WASTES[1]

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ABSTRACT

A process was developed for simultaneous utilization of several food wastes and production of single cell protein by successive growth of Bacillus subtilis *and* Lactobacillus acidophilus. *A collagen-derived substrate, starch, and cheese whey represented food wastes. Growth of* B. subtilis *on combined wastes yielded a biomass of* 3.6 *g/l and significantly modified the medium. Other bacilli also had similar potential for altering the original material. After fortification with cheese whey, the modified medium was used for growth of* L. acidophilus *as a second stage biomass production. Optimal growth conditions were determined. The feasibility of the process will be dependent upon increasing* L. acidophilus *biomass yields.*

INTRODUCTION

Much of the reported work on processes for producing microbial protein for human and animal consumption has focused on the fermentation of hydrocarbons and alcohol (Cooney *et al.* 1975; Shacklady 1974; Slater 1974). Although favorable publicity has accompanied these efforts, the scarcity of petroleum products may cause hydrocarbon substrates to become too expensive to support an economically viable single cell protein (SCP) industry in the future.

One of the most economically and ecologically promising alternatives is the utilization of industrial and food wastes as substrates for SCP production (McLoughlin 1972). When the substrate is not a waste material, cost may contribute as much as 15% to the total production

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cost of SCP (Kosaric *et al.* 1974). Considerable savings can be realized when waste materials are used, not only by reducing substrate costs but also by reducing waste disposal expense and problems.

Waste materials are often complex and composed of substances such as cellulose or collagen that many microorganisms cannot readily utilize (Bellamy 1974; Bough *et al.* 1972). In the production of SCP, the type of microorganism used has a distinct bearing on utilization of a specific substrate and the subsequent quality of protein. Traditionally, if the organism is incapable of utilizing the waste directly, either chemical, enzymatic, or mechanical pretreatments have been used to break down waste materials and provide a growth medium suitable for SCP production. The microorganisms that can utilize the waste materials directly may not produce high quality SCP. However, these microorganisms can be utilized as pretreatment for subsequent microbial growth. The organism with enzymatic capacity to utilize the waste material directly is grown first and the products of its growth are used to support the growth of a higher quality SCP organism. An example is the Symba yeast process (Emmelin 1974). A mixed culture containing a saccharolytic fungus, *Endomycopsis fibuligis*, and a *Torula* yeast was grown on waste water from a potato processing plant. The fungal amylase(s) produce glucose and short-chain oligosaccharides which serve as substrates for the production of yeast biomass.

In this paper the feasibility of a process designed to take advantage of the economy of waste materials as substrates is described. The use of microbial action for the prior degradation of complex wastes followed by production of SCP by another microorganism also takes advantage of using several food waste materials in combination to eliminate expensive substrate adjuncts. A preliminary report on this process has been made (Schmidt *et al.* 1975).

MATERIALS AND METHODS

Cultures

Bacillus subtilis A, *Lactobacillus acidophilus*, *Lactobacillus lactis*, and *Lactobacillus casei* were obtained from the culture collection maintained by our laboratory. *Bacillus polymyxa* ATCC 8523 was obtained from the American Type Collection. *Bacillus megaterium* was obtained from the Carolina Biological Supply Company, Burlington, North Carolina (Item 15-4900). *Bacillus natto* was obtained from the Institute for Fermentation, Osaka, 532, Japan (Item 3936).

A collagen-derived substrate, SP-100, supplied by Oscar Mayer and

Company, Madison, WI, was chosen to represent meat packing wastes. Reagent grade soluble starch (Mallinckrodt) represented corn or potato processing wastes. Dried cottage cheese whey for medium fortification was supplied by Land O'Lakes, Inc., Minneapolis, MN.

Growth Measurement

Optical density was used in evaluating the growth of all bacteria. A 3-ml volume of culture medium in a 13 × 100-mm cuvette was measured at 650 nm using a Bausch and Lomb Spectronic 20 spectrophotometer.

Preparation of Bacilli for Growth and Medium Modification

One-milliliter portions of a suspension containing *B. subtilis* spores (10^8/ml) were transferred to 10 ml sterile (121°C for 15 min) 0.1% peptone in 16 × 100-mm screw cap test tubes. The spores were heat shocked (90°C for 1 hr) and germinated in 25 ml of test medium in 125-ml screw cap Erlenmeyer flasks. The flasks then were shaken at 200 rpm for 12–16 hr at 37°C. Inocula from these flasks corresponding to 1 ml of culture (0.1 OD) were transferred to a second set of flasks containing test media. The second set of flasks were shaken as before for the length of time specified in the experimental design.

Preparation of cultures of *B. polymyxa*, *B. megaterium*, and *B. natto* used in growth studies in 50 g/l collagen, 10 g/l starch medium was identical to *B. subtilis* culture preparation except the initial inoculum was subcultured from nutrient agar slants rather than germinated spores.

Preparation of Lactobacilli for Growth in Modified Media

Inocula of 0.1 ml of coagulated 11% reconstituted skimmilk cultures were transferred into tubes containing 10 ml Elliker's broth medium (Elliker *et al.* 1956). These cultures were incubated for 10–14 hr, transferred once in the same broth medium, harvested in sterile centrifuge tubes at 12,100 × g for 10 min using an RC-2 refrigerated Sorvall centrifuge. The cells were washed once in sterile phosphate buffer (0.1 M, pH 7.0) and resuspended in the same buffer (0.1 OD). A 1-ml portion of the washed inoculum was then transferred to each 16 × 150 mm tube containing ca. 23 ml of modified medium prepared as indicated below. *L. acidophilus* was cultured at 37°C. *L. casei* and *L. lactis* were cultured at 32°C.

Preparation of Media and Modified Media

A stock solution containing 160 g/l of collagen was made up and the pH was adjusted to 7.0. This solution was distributed to standard wide mouth 100-ml dilution blank bottles (100 ml/bottle) and autoclaved at 121°C for 15 min. Dilution blanks containing 100 ml of 20 g/l soluble starch solution were prepared in a similar manner. The pH of the starch solution was not adjusted.

These sterile collagen and starch solutions were mixed in the proper proportion and sterile distilled water was added to give a medium with the indicated specific composition. The medium was distributed in 25-ml portions into 125-ml screw cap Erlenmeyer flasks. The entire procedure was carried out aseptically in a laminar flow hood.

To prepare the modified medium, initially the *Bacillus* sp. under consideration (generally *B. subtilis*) was inoculated in the manner described above. At the end of the specified growth period, 50 mg of lysozyme per flask was added and the flasks were incubated for 1 hr at 37°C. When necessary, cheese whey was added at this point in the preparation. The flasks were then autoclaved at 121°C for 15 min.

The sterile contents of each flask were centrifuged in sterile centrifuge tubes for 10 min at 12,100 × g. The supernatant fluid (ca. 23 ml) which served as the modified medium was poured into sterile screw cap 16 × 150-mm tubes and inoculated as indicated above with lactobacilli for growth studies.

Protein Determination

Protein was determined according to the micro-Kjeldahl method (AOAC 1970). Instead of HgO and K_2SO_4, SeOCl in the amount of 12 g/l was added to the H_2SO_4 as a catalyst and 4.0 ml of this reagent was added to the digestion flasks. Instead of the NaOH-$Na_2S_2O_3$ solution, 10–15 ml of 40% NaOH was added prior to distillation. The biomass protein content was determined using the conversion factor 6.25 as recommended by the PAG (Protein Advisory Group 1973).

Dry Cell Weight Determination

The 25-ml samples of culture medium containing growing cells were placed in tared centrifuge tubes and centrifuged at 3020 × g for 10 min in a refrigerated centrifuge. The biomass pellet was resuspended in distilled water and sedimented as before in the tared centrifuge tube. The tubes containing the biomass pellets were dried overnight at 121°C and weighed. The quantity of biomass was expressed as grams dry weight of cells/liter of culture medium.

Carbohydrate Determination

A 5-ml sample of modified medium was pipetted into a 17 X 100-mm centrifuge tube. Equal volumes (2.5 ml) of 2% $ZnSO_4 \cdot 7H_2O$ and 0.46% NaOH were added sequentially with agitation between and after additions (equal meq of H^+ and OH^-; tested with phenolphthalein). The precipitate was separated from the supernatant by centrifugation at 6000 X g for 10 min. Samples were taken from the supernatant for starch and reducing sugar analyses.

Reducing sugar was determined by the method of Shaffer and Somogyi (AOAC 1970) and expressed as g/l maltose. Starch was qualitatively determined by the addition of 1% I_2-KI to the clarified solutions and observation of the characteristic starch-iodine complex blue color reaction.

Zones of Starch Hydrolysis

The four species of *Bacillus* under consideration were plated on nutrient agar containing 0.2% soluble starch. After 24 hr of incubation the plates were flooded with 1% I_2-KI and the zones of hydrolysis were observed.

Experimental Design

The experimental design was based on statistical response surface methods according to models provided by Davies (Davies 1971). All computations were made utilizing computer programs provided by the Pillsbury Co., Minneapolis, MN. On each response surface (Fig. 2, 3, 4, 5), F values are given. F_1 is an indication of how well the model predicted the experimental error encountered. F_2 is an indication of the appropriateness of the model as a tool in analyzing the data obtained. These values are followed by symbols indicating their significance. The absence of a symbol indicates that the F value was not significant at the level of significance tested, * indicates significance at the 5% level, ** indicates significance at the 1% level, and *** indicates significance at the 0.1% level. Designed experiments were run in quadruplicate. Figure 1 describes the model process followed in all experiments.

RESULTS

Selection of Optimal Substrate Concentration and Associated Variables

A preliminary study showed that collagen concentration was the

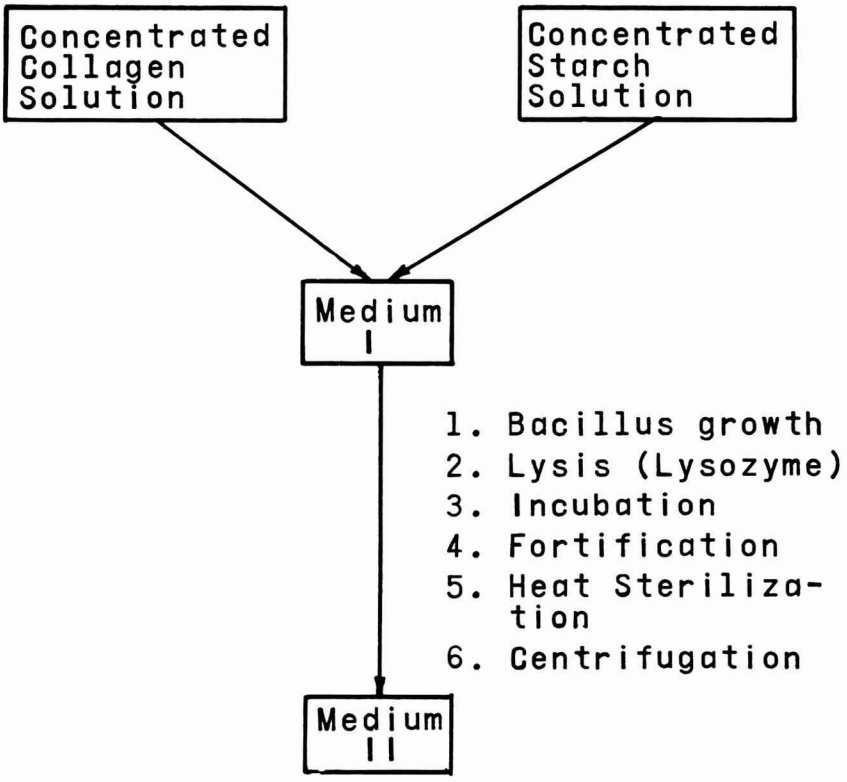

FIG. 1. SCHEMATIC DIAGRAM OF THE MODEL PROCESS FOLLOWED IN THE RESPONSE SURFACE EXPERIMENT

main factor influencing the growth of *B. subtilis* and *L. acidophilus* (data not shown). From this preliminary study, collagen concentrations were selected in a range from 20–80 g/l and starch concentrations were tested from 2–10 g/l.

Figure 2 shows the response surface from data relating the level of *B. subtilis* growth (4 hr at 37°C) to collagen and starch concentration. This surface shows a plateau above 50 g/l of collagen. Collagen had a large and significant effect on *B. subtilis* growth at concentrations below 40 g/l, as indicated by the spacing of the contour lines. No potential for better growth is indicated at collagen concentrations above 80 g/l. Starch concentration had little effect on *B. subtilis* growth.

The response surface from data on reducing sugar accumulation after 4 hr of *B. subtilis* growth at 37°C (Fig. 3) indicates that increased

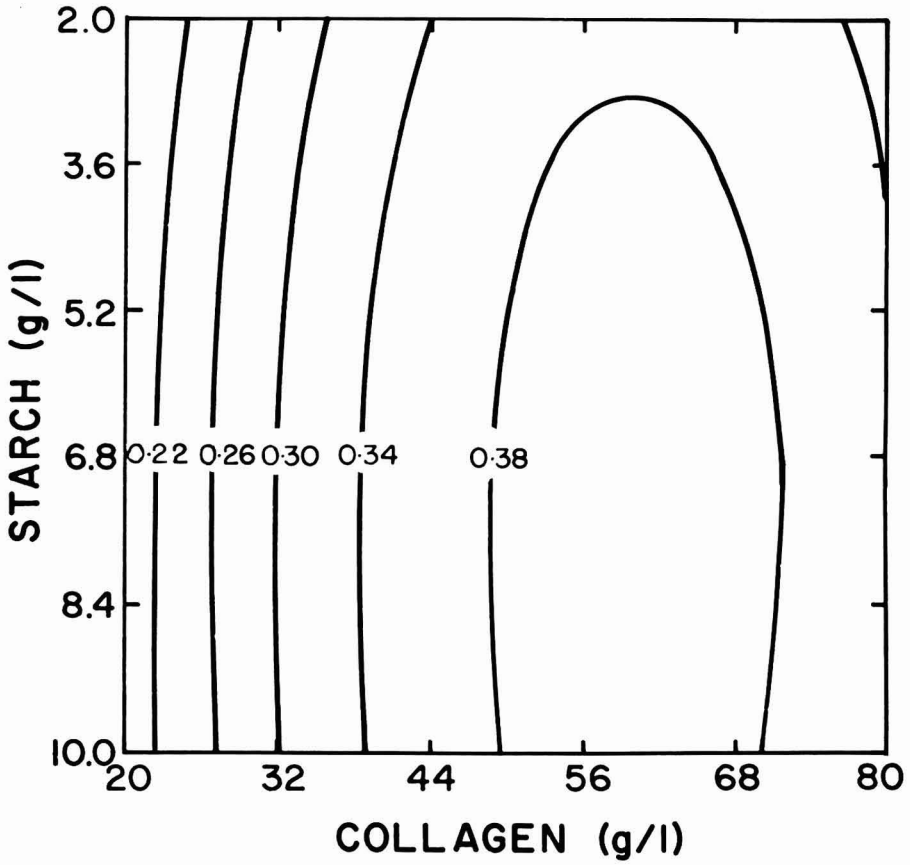

FIG. 2. RESPONSE SURFACE RELATING *BACILLUS SUBTILIS* GROWTH (NUMBERS ON CURVES INDICATE OD AT 650 NM AFTER 4 HR @ 37°C) TO COLLAGEN AND STARCH CONCENTRATION (G/L)

$F_1 = 10.2$, ***; $F_2 = 1.1$, N.S.

amounts of reducing sugar were related to increased collagen and starch concentrations. This rising ridge relationship shows a significant interaction between collagen and starch when starch hydrolysis is measured. At higher levels of collagen, changing starch concentration had a greater effect on reducing sugar accumulation.

Several important trends can be recognized by an evaluation of the response surfaces for *L. acidophilus* growth on media modified by *B. subtilis* growth. In modified media fortified with 3.44 g/l cottage cheese whey (Fig. 4), increased amounts of *Lactobacillus* growth, although at relatively low levels, were observed with increases in collagen and starch

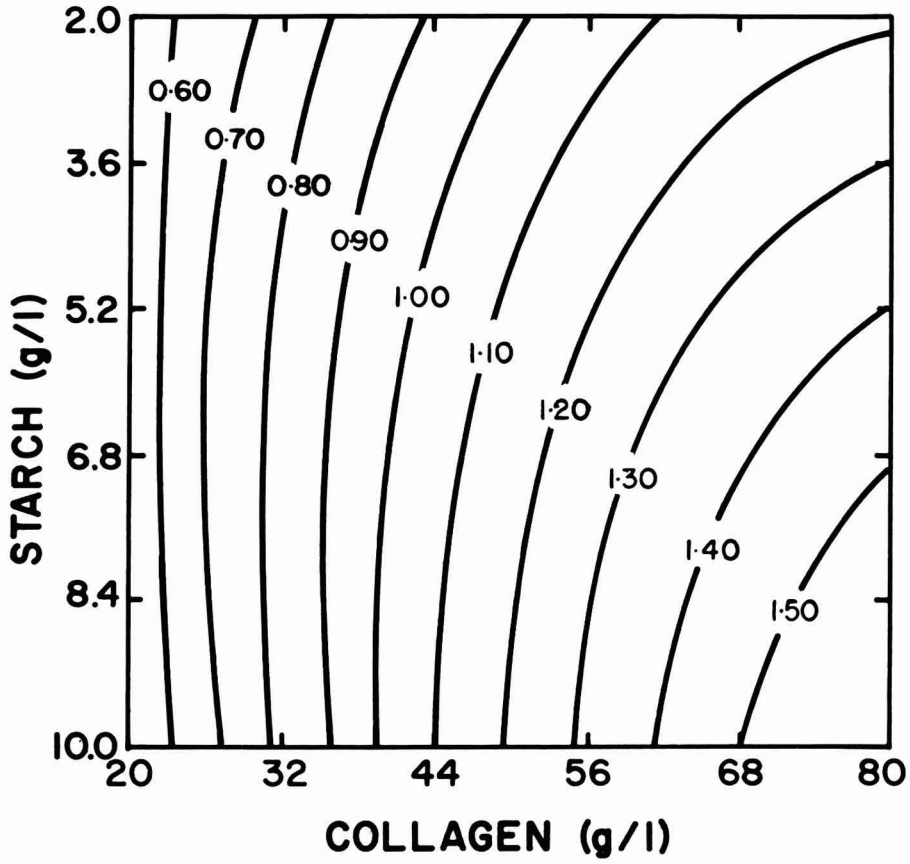

FIG. 3. RESPONSE SURFACE RELATING REDUCING SUGAR ACCUMULATION DURING *BACILLUS SUBTILIS* GROWTH (NUMBERS ON CURVES INDICATE G/L MALTOSE AFTER 4 HR @ 37°C) TO COLLAGEN AND STARCH CONCENTRATION (G/L)

$F_1 = 59.3$, ***; $F_2 = 1.4$, N.S.

concentrations. The optimum collagen concentrations for *L. acidophilus* growth were similar to those for *B. subtilis* growth. In the presence of cottage cheese whey, starch concentration had a relatively large effect even at the lower levels of *L. acidophilus* growth.

The growth of *L. acidophilus* in unfortified media (Fig. 5) reached only low levels. This response surface from data on unfortified modified media shows that increasing amounts of *Lactobacillus* growth were obtained with increased concentrations of collagen. Dependence on starch concentration also was indicated. Increased collagen concentra-

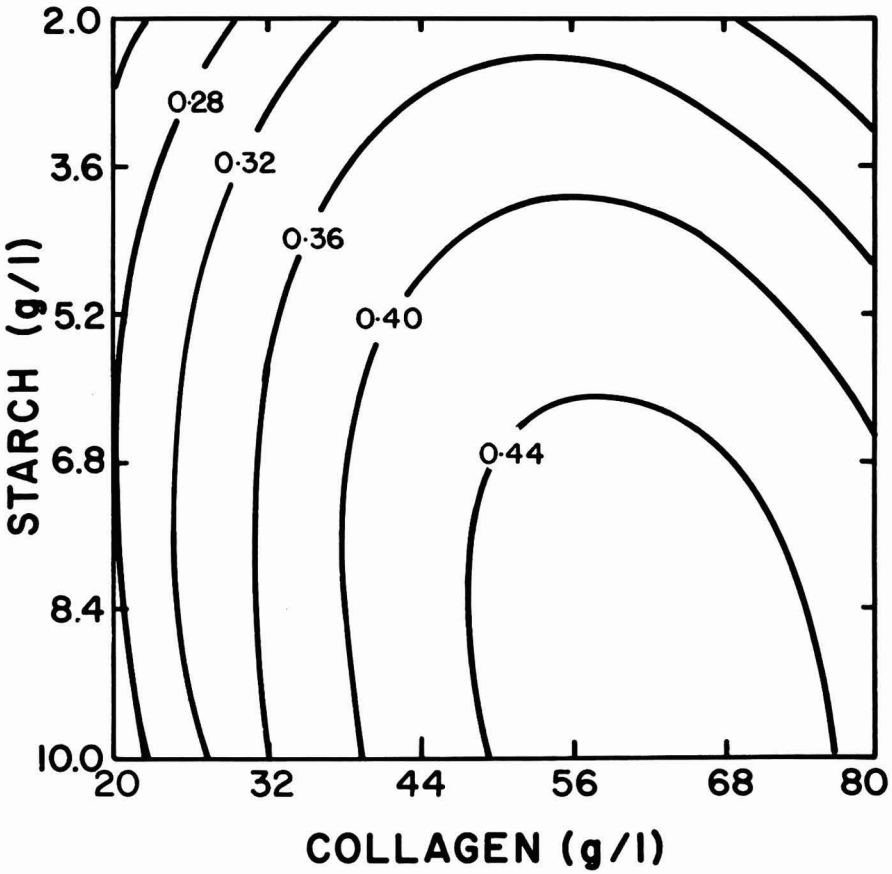

FIG. 4. RESPONSE SURFACE SHOWING *LACTOBACILLUS ACIDOPHILUS* GROWTH (NUMBERS ON CURVES INDICATE OD AT 650 NM AFTER 24 HR @ 37°C) IN COLLAGEN-STARCH (G/L) MEDIA MODIFIED BY *BACILLUS SUBTILIS* GROWTH (4 HR @ 37°C) AND FORTIFIED BY THE ADDITION OF 3.44 G/L OF COTTAGE CHEESE WHEY

$F_1 = 3.6$, N.S.; $F_2 = 20.9$, *.

tions at moderate levels of starch resulted in increased levels of *L. acidophilus* growth.

On the basis of these experiments, a medium composed of 50 g/l collagen and 10 g/l starch was selected for use in subsequent experiments measuring the accumulation of reducing sugars, production of biomass during *B. subtilis* growth and in comparative growth studies using other bacilli.

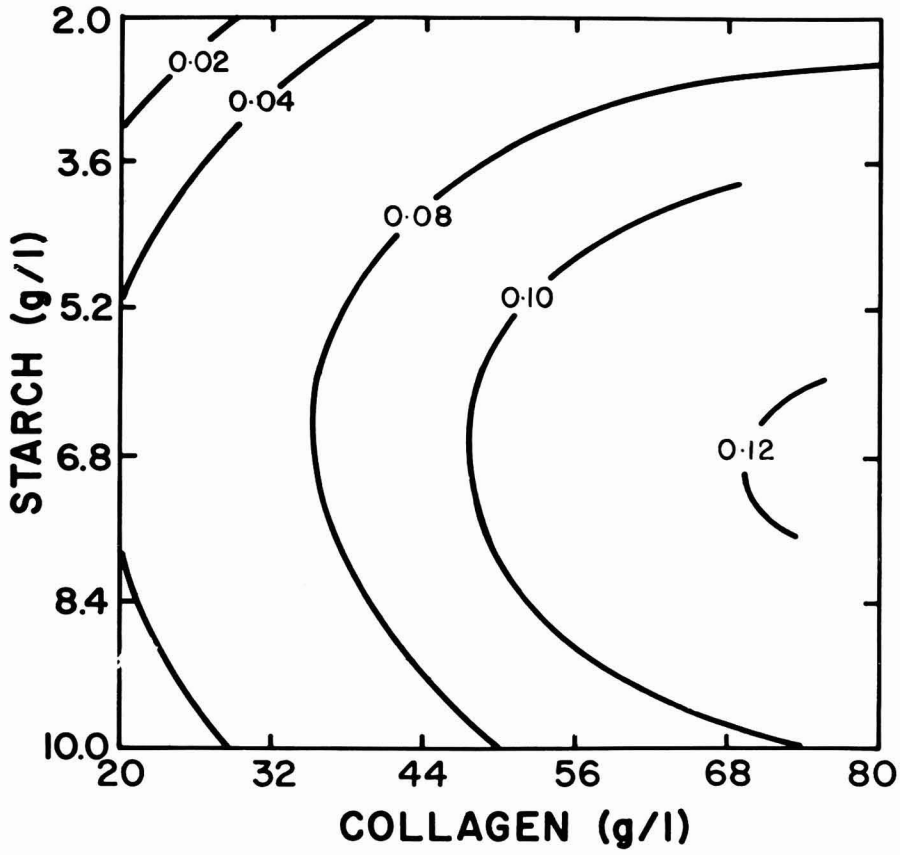

FIG. 5. RESPONSE SURFACE SHOWING *LACTOBACILLUS ACIDOPHILUS* GROWTH (NUMBERS ON CURVES INDICATE OD AT 650 NM AFTER 24 HR @ 37°C) IN COLLAGEN-STARCH MEDIA (G/L) MODIFIED BY *BACILLUS SUBTILIS* GROWTH (4 HR @ 37°C)

$F_1 = 21.9$, **; $F_2 = 6.3$, N.S.

Biomass Production

In Fig. 6, *B. subtilis* biomass production is related to incubation time. Biomass increased directly and essentially linearly with time, and appeared to be still increasing at 24 hr when the experiment was terminated. The maximum dry cell weight obtained at 24 hr was 3.6 mg/ml of culture medium. The protein content (Kjeldahl N × 6.25) was about 60%.

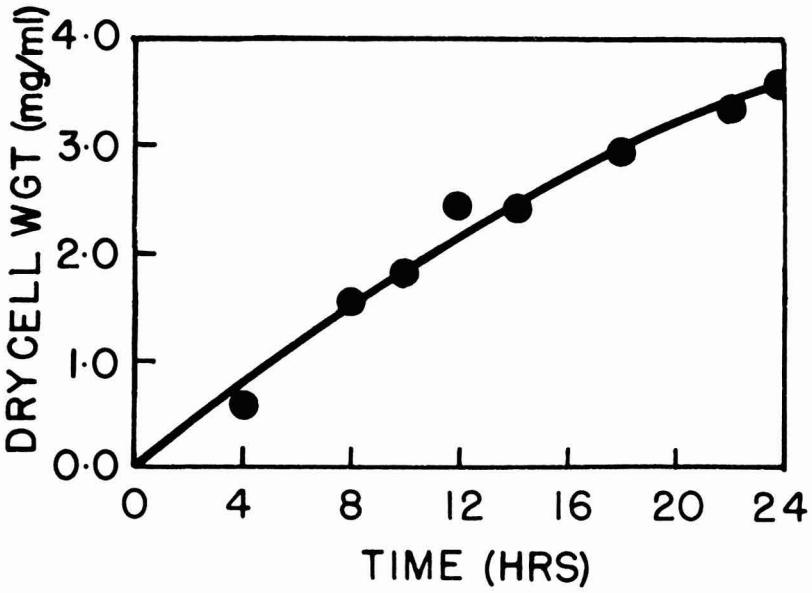

FIG. 6. *BACILLUS SUBTILIS* GROWTH AT 37°C AND BIOMASS PRODUCTION (DRY CELL WEIGHT) IN COLLAGEN (50 G/L)-STARCH (10 G/L) MEDIUM

Medium Modification Indicated by Reducing Sugar Accumulation

Accumulation of reducing sugar in media containing lysed *B. subtilis* cells was greater than in media containing growing cells (Fig. 7). In the medium containing growing cells, the reducing sugar concentration reached a maximum value after 12 hr of growth and subsequently decreased. In the medium where the cells were lysed, the maximum reducing sugar concentration was twice that obtained with growing cells.

Alternate Species of Bacillus and Lactobacillus

A comparison of the growth of several species of *Bacillus* in the specified collagen-starch medium (Table 1) indicated that *B. subtilis* and *B. megaterium* gave the most abundant growth. *Bacillus natto*, a variety of *B. subtilis*, gave good but less abundant growth. The growth of *B. polymyxa* compared unfavorably with that of the other species.

Amylase production by the four species of *Bacillus* was estimated by observing zones of hydrolysis in starch agar (Fig. 8). *Bacillus megaterium* and *B. polymyxa* showed approximately the same

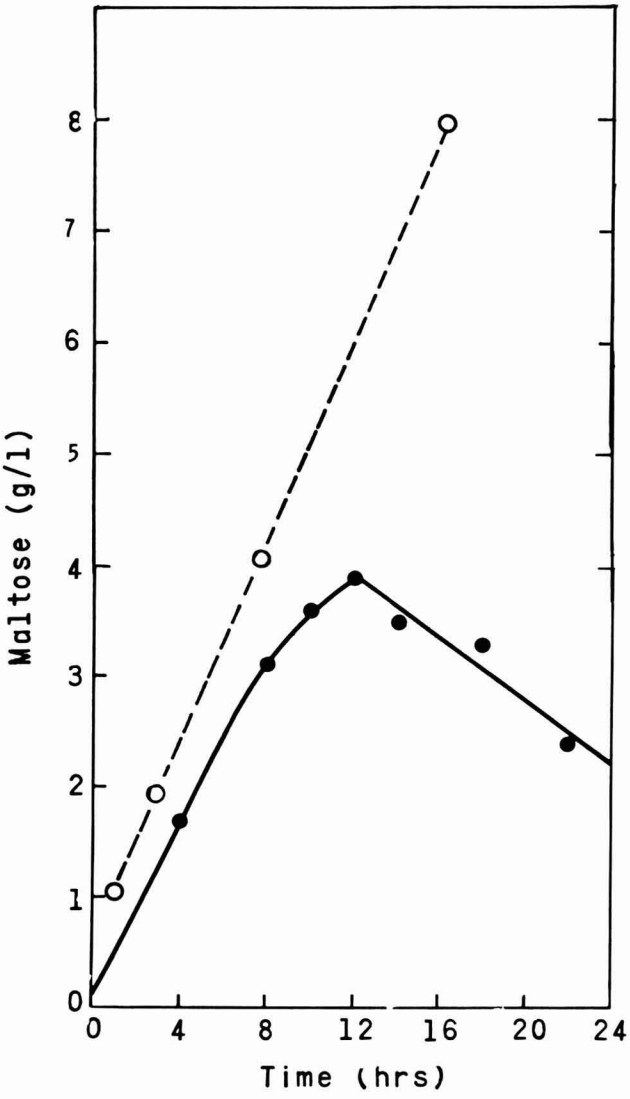

FIG. 7. REDUCING SUGAR ACCUMULATION IN COLLAGEN (50 G/L)-STARCH (10 G/L) MEDIUM DURING *BACILLUS SUBTILIS* GROWTH

Closed circles and solid line data on whole cells after 4 hr at 37°C. Open circles and broken line data after lysis of 4 hr cells.

Table 1. Growth of several species of *Bacillus* (OD 650 nm) in medium composed of 50 g/l collagen and 10 g/l starch

Time (hr)	*Bacillus megaterium*	*Bacillus natto*	*Bacillus polymyxa*	*Bacillus subtilis*
2	0.02	0.02	0.015	—
4	0.18	0.14	0.06	0.38
6	0.58	0.52	0.23	—
8	—	—	—	1.50
23	4.80	3.90	1.38	—
24	—	—	—	4.38

Table 2. Growth of several species of *Lactobacillus* in medium initially containing 50 g/l collagen and 10 g/l starch modified by *Bacillus subtilis* growth (4 hr at 37°C)

		Lactobacillus acidophilus	*Lactobacillus casei*	*Lactobacillus lactis*
No fortification	OD	0.10	0.04	0.04
	pH	6.2	6.3	6.6
Cottage cheese whey (3.44 g/l)	OD	0.38	0.32	0.23
	pH	4.5	4.8	5.1

relationship between zones of hydrolysis and colony size. *Bacillus polymyxa* colonies were much smaller. *Bacillus natto* and *B. subtilis* gave smaller zones of hydrolysis relative to colony size but the overall size of zones was similar to those of *B. polymyxa.*

The growth of three species of *Lactobacillus* was compared in fortified and unfortified modified media. Growth in the unfortified modified medium was insignificant for all three species. *Lactobacillus acidophilus* produced slightly greater turbidity in either medium. A lowering of the pH was noted with all three species. *Lactobacillus casei* gave a pronounced odor of diacetyl in both fortified and unfortified modified media.

DISCUSSION

The process for simultaneous utilization of food wastes and production of SCP developed here was complex. Three variables were tested:

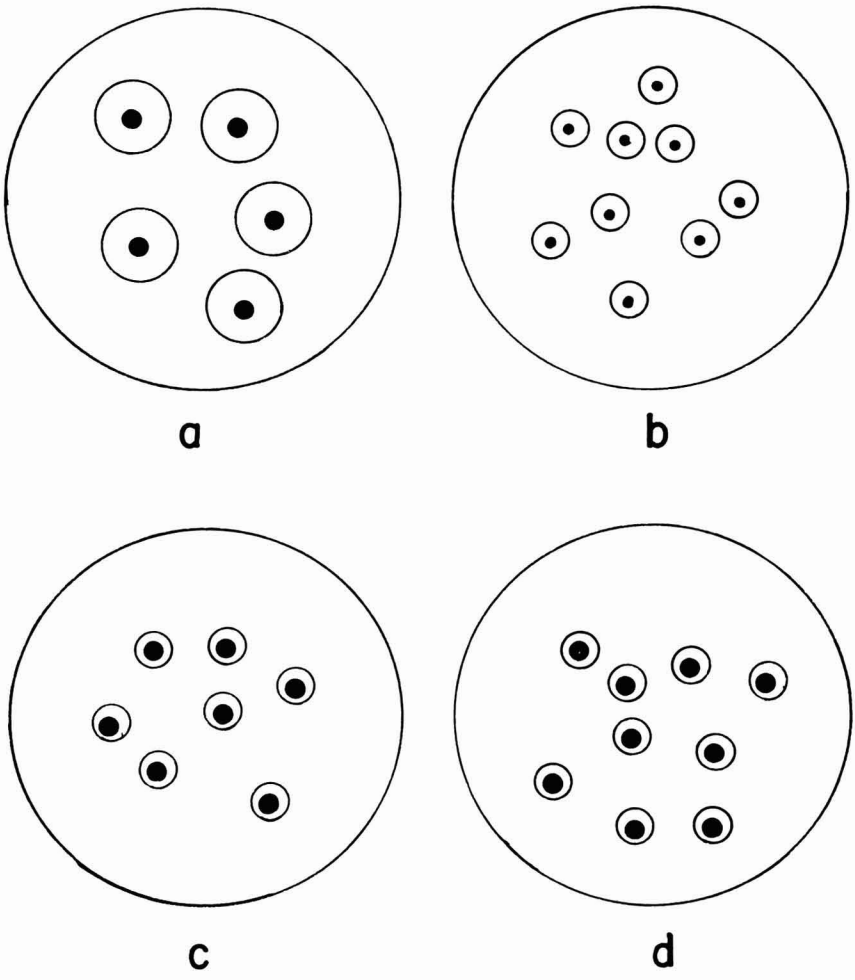

FIG. 8. ZONES OF HYDROLYSIS AROUND COLONIES OF *BACILLUS MEGATERIUM* (A), *BACILLUS POLYMYXA* (B), *BACILLUS NATTO* (C), AND *BACILLUS SUBTILIS* (D) IN STARCH AGAR

collagen concentration, starch concentration, and harvest time of *B. subtilis*. Three responses were measured: growth of *B. subtilis*, reducing sugar accumulation, and growth of *L. acidophilus*. The potential value of the process justified the complexity.

The appropriateness of the experimental design and the model in accounting for experimental error and explaining the observed data was confirmed by statistical analyses in all cases but one. The F values in Fig. 4 indicate that the model did not predict the experimental error

very well and that the model was not appropriate in analyzing the data obtained. This may be explained by the relatively low levels of growth and the fact that cheese whey was added prior to *L. acidophilus* growth in these experiments. Both of these factors tended to decrease any variation in the data, and this resulted in a lack of information by which the computer could predict experimental error.

Broad optima, such as those indicated in the response surface plots, are essential for the efficient use of substrates, such as food plant wastes, which are not constant in composition. Figure 2 shows that, in the optimal range, a sizeable shift in collagen and starch concentration had little effect on *B. subtilis* growth.

On a dry weight basis, *B. subtilis* gave very good yields in the optimum collagen starch medium. While these data were obtained in batch culture, the short generation time indicates that equally good yields could be obtained in continuous culture. Based on a comparison of maximum OD in the selected medium, *B. megaterium* and *B. natto* would do as well or better in this system.

While Kjeldahl nitrogen has been criticized as a method of determining protein content in SCP due to the relatively high concentration of other nitrogen-containing compounds in microbial cells, the Protein Advisory Group (PAG) of the United Nations has recommended its use (1973). The protein content of *B. subtilis* biomass, as determined by Kjeldahl N analysis using a conversion factor of 6.25, was 60%. This is approximately the same as the maximum crude protein content measured by Bough *et al.* (1972) in their work with *B. megaterium*. While we did not measure the quality of the protein obtained from a nutritional standpoint, Bough *et al.* (1972) indicated that good quality protein can be produced in this way.

The data showed that *B. subtilis* is capable of hydrolyzing the starch present in the medium giving high yields of reducing sugar in a short time. *Bacillus subtilis* amylase remained active after the cells had been lysed resulting in higher yields of reducing sugars. In comparative studies (Fig. 8), *B. megaterium* gave larger zones of hydrolysis relative to colony size than *B. subtilis*. Maximum starch hydrolysis is important in providing the best possible medium for carrying out the second stage of the process that aids in reducing the B.O.D. of the waste.

We were unable to determine what, if any, effect the growth of *B. subtilis* had on the collagen. Experiments measuring the decrease in N content of the medium relative to *B. subtilis* growth failed to show a significant change. However, the work of Bough *et al.* (1972) showed that efficient use of collagenous nitrogen can be realized in continuous culture.

Lysozyme was used as a method of breaking down the cell walls of *B. subtilis* to facilitate the harvesting of the intracellular protein. Although the effectiveness of this treatment was made apparent by the studies on starch hydrolysis, the expense of using purified enzymes on an industrial scale could be prohibitive unless an immobilized enzyme system is used. Datta *et al.* (1973) showed that immobilized lysozyme was nearly as effective as free lysozyme in lysing cells of *Micrococcus lysodeikticus*.

The growth and protein production of *L. acidophilus* on the medium was disappointing. Most of the work concentrated on the performance of the bacilli; therefore, the reason for the poor performance of the lactobacilli was not determined. It was noted that the pH declined quite rapidly in many of the *L. acidophilus* trials. Controlling the pH is one method which should be assessed in trying to increase the yield of these organisms.

Bacillus megaterium may be a better choice than *B. subtilis* as the first organism in the process. Comparative studies indicated that it gave higher yields when grown in the optimum medium and that it produced a greater quantity of amylase. In addition, prior work has shown that its protein has a good PER (Bough *et al.* 1972). The choice of *L. acidophilus* as the second organism does not appear to be especially advantageous from the standpoint of protein yield. Its advantages as an SCP organism, such as ability to grow at a low pH and its prior use as a food organism, cannot be realized until this yield problem is solved. Nevertheless, in this feasibility study, the process with some modifications appears to have great potential.

ACKNOWLEDGMENTS

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EVALUATION OF THE ABBEON CUP ANALYZER COMPARED TO THE VPM AND FETT-VOS METHODS FOR WATER ACTIVITY MEASUREMENT

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ABSTRACT

Many methods are available for measurement of water activity. A simple hair hygrometric cup device was compared to the vapor pressure manometric and Fett-Vos techniques. If precautions are taken to ensure equilibrium, it was found to be a reliable method for high a_w (0.7 to 0.95) food systems and thus could be used in quality control.

INTRODUCTION

Water activity (a_w) directly controls most chemical reactions as well as microbiological activity in food systems and formulations (Labuza 1975), and thus is an important consideration in the manufacture of food items. For this reason there is a demand in the food industry for relatively accurate, convenient and inexpensive methods of measuring a_w that personnel in food processing plants can use. In this study a simple cup device, consisting of a filament hygrometer used to a great extent for quality control in the German food industry, was compared statistically with the Fett/Vos method and the VPM procedure. Labuza *et al.* (1976) reported a large difference in values obtained between different a_w methods, but no statistical comparisons were made.

The Abbeon cup analyzer is used as a quality control method for a_w measurement in the German meat industry (Leistner and Rodel 1975). Rodel *et al.* (1975) measured the water activity of thirty-seven meat products with the aid of a Sina apparatus, an electric hygrometer

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(Zurich, Swiss), and the Abbeon device. Over ten measurements were made on each meat product. It was found that 178 measurements were different from the electric hygrometer value by ±0.5%, and 311 were different by ±1%. Reproducibility of the Abbeon type device in two successive measurements was equal to ±0.26 and ±0.36% of the measured value at a_w = 0.969 and 0.966 respectively. The standard deviation was equal to ±0.0025 and ±0.0035 a_w units, respectively.

METHODS

Abbeon Cup Analyzer

The Abbeon cup analyzer model #5803 is made in West Germany and marketed by Abbeon Cal Inc., 123-1A Gray Avenue, Santa Barbara, CA 93101. The sensing system set up in a round metal casing consists of a moisture vapor sensitive monofilament attached to finely calibrated springs. Holes at the bottom of the casing admit air to the sensor. The dial is calibrated in 0.01 units between a_w 0.7 to 1.0, but reads between a_w 0.4 to 1.0. Equilibrium time is about 3 hours (at room temperature) according to the instructions. Also on the dial is a temperature indicator. Since a_w readings are temperature dependent, a table of correction factors is given for each degree deviation within ±5°C of the temperature at which the instrument is calibrated. The analyzer should be calibrated periodically at 20°C using a saturated solution of barium chloride (a_w = 0.90) and adjusting the indicator to this value with a set screw (about once per week).

To carry out an a_w measurement, the sample was placed in a metal container clamped to the instrument casing. The cups were held at 20°C for three hours at which time the a_w value was read directly from the dial. After each measurement the sensor was placed over desiccant overnight. The sensor was recalibrated for each different type of sample tested in this study.

VPM Method

Details of using the vapor pressure manometer (VPM) were presented by Labuza *et al.* (1976). This method can be used between a_w 0.0 and 0.98 with a high degree of accuracy and precision (±0.01 a_w). For the saturated salt solutions tested, the samples were combined from the duplicates of the solutions used for the cup analyzer.

Fett-Vos — Isopiestic Method

This method uses the absorption of water from the food onto a known dry absorbing material as described by Vos and Labuza (1974). Microcrystalline cellulose is used as the absorbent. The isopiestic method should only be used between a_w about 0.78 and 0.95.

Samples

Each salt or food sample tested was a fresh sample out of a large pooled batch. In the analysis of some of the food samples a comparison was made between two technicians.

RESULTS

The accuracy of the Abbeon a_w analyzer was measured using saturated salt solutions and comparing to both literature values and to values measured by the vapor pressure manometer on the same solutions. The results are shown in Table 1 and show that the Abbeon values are not exact as compared to literature values or to the VPM measurements in all cases. Duplicate measurements of the same sample are close but the value changed when another sample of the same a_w was tested for two salts.

Table 1. Check of a_w analyzer on standard solutions

Saturated Salt Solution	Literature Value	VPM	Abbeon Cup Analyzer		
			Sample I	Sample II	Sample III
NaCl	0.75	0.745	0.765	0.760	—
		0.749	0.769	0.744	—
Avg		0.75	0.77	0.75	—
K_2CRO_4	0.88	0.850	0.850	0.872	0.866
		0.855	0.850	0.871	0.862
Avg		0.85	0.85	0.87	0.87
$BaCl_2$	0.91	0.902	0.903	0.904	—
		0.891	0.903	0.904	—
Avg		0.90	0.90	0.90	—
$LiSO_4$	0.85	0.839	0.854	0.850	—
		0.830	0.852	0.846	—
		0.831	—	—	—
Avg		0.83	0.85	0.85	—

Analysis of variance of the data as seen in Table 2 shows a significant difference between a_w's measured by the VPM and Abbeon device. At the 0.05 probability level the F value for differences between analyzers is much greater than the theoretical value at the 95% level. It was calculated that the a_w of the standard solutions was measured with a reproducibility of ±0.0069 by either method. The difference between the two methods amounts to ±0.0152 a_w units. This is probably within the degree of usefulness if the Abbeon method is to be used only as an industrial quality control device assuming that the VPM can be used as a standard.

Table 2. Analysis of variance: Check of a_w analyzer on standard solutions (data of Table 1)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	$F^{0.05}$ Table
Between solutions	0.045929500	3	0.015309833	257.85	4.07
Between analyzers	0.000506250	1	0.000506250	8.53	5.32
Interaction	0.000042250	3	0.000014083	0.24	4.07
Within analyzers (error)	0.000475000	8	0.000059375	—	—
TOTAL	0.046953000	15			

The results of the a_w found for four meat samples measured by all three methods are presented in Table 3 and analyzed statistically in Table 4. All measurements were done by one technician. Analysis of variance of these data shows that there is a significant difference between a_w values obtained for the same meat sample by the three investigated methods. The reproducibility of the methods is estimated to be ±0.0169. This is almost three times greater variation than that for standard salt solutions as was found in the results of Labuza *et al.* (1976). Much lower reproducibility of the methods can be assigned to inhomogeneity of the material examined. The difference between a_w measured by the three methods amounts to ±0.0382 units which is quite large, but also similar to that found by Labuza *et al.* (1976).

The reproducibility of each investigated method was determined by one technician using Parmesan cheese and Quaker Oats Special Cuts® (IMF) dog food as samples. The data are in Table 5 and the statistical comparison is shown in Table 6. As seen in this study the VPM method

Table 3. Measurement of a_w of meat samples

	Fett-Vos	a_w VPM	Abbeon Cup Analyzer
Thuringer	.962	.987	.934
(Brand A)	.937	.999	.926
	.960	—	.924
	.952	—	—
Avg	0.95	0.99	0.93
Hard Salami	.822	.851	.782
(Brand A)	.840	.833	.788
	.840	—	.790
	.835	—	—
Avg	0.83	0.84	0.79
Thuringer	.998	.993	.898
(Brand B)	.984	.993	.898
	.990	—	.916
	.982	—	.912
Avg	0.99	0.99	0.91
Hard Salami	.860	.939	.852
(Brand B)	.848	.879	.836
	.858	—	.845
	.862	—	.845
Avg	0.86	0.91	0.84

Table 4. Analysis of variance: Measurement of a_w of meat samples (data of Table 3)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	$F^{0.05}$ Table
Between samples	0.043128666	3	0.014376222	50.45	4.76
Between methods	0.009345500	2	0.004672750	16.40	4.15
Analytical error	0.001709834	6	0.000284972	—	—
TOTAL	0.054184000	11			

Table 5. Results of multiple analysis for a_w determination by three methods

Fett/Vos	Abbeon Cup Analyzer	VPM
	Parmesan Cheese	
.742	.738	.676
.730	.732	.669
.715	.737	.680
.710	.728	.680
.730	.748	.680
.725	.742	.683
.739	.698	.679
.739	.698	.684
.724	.737	.677
.730	.734	.681
.730	.733	—
.730	.739	—
.730	—	—
.718	—	—
.728	—	—
.739	—	—
.718	—	—
.710	—	—
Avg .727	.730	.679
SD = ±0.0097	SD = ± 0.015927	SD = ±0.00423
	Special Cuts	
.840	.844	.801
.838	.846	.787
.858	.838	.779
.848	.840	.780
.855	.838	.791
.855	.838	.793
.842	.858	.800
.844	.858	.795
.838	.840	.780
.844	.838	.788
.825	—	—
.822	—	—
.840	—	—
.844	—	—
.808	—	—
.802	—	—
.792	—	—
.788	—	—
.818	—	—
.825	—	—
Avg .831	.844	.789
SD = ±0.02067	SD = ±0.00797	SD = ± 0.00807

Table 6. Statistical comparison of methods (data from Table 5)

	Methods Compared	t Value for the Difference Between Means	Comparison of Variances, F Values	$F^{0.05}$ Table
Parmesan cheese	Fett-Vos/Abbeon	0.64	2.68	2.34
	Fett-Vos/VPM	18.14	5.29	2.77
	Abbeon/VPM	10.74	14.19	2.91
Special Cuts	Fett-Vos/Abbeon	2.37	6.73	2.77
	Fett-Vos/VPM	7.94	6.56	2.77
	Abbeon/VPM	15.17	1.03	2.98

gave lower values than either the Fett-Vos or the Abbeon device. The difference between average a_w values for the Fett-Vos and the Abbeon device is not statistically significant for Parmesan cheese (Table 6). For Special Cuts the difference is significant but small. The data from Table 5 indicate that the precision of the methods also varies between methods and between samples. The VPM as was found in the previous study showed the best overall reproducibility.

The three methods were also compared for a number of food items, with the results shown in Table 7 using numerous replicates in most cases, and in this case two technicians designated as A and B. As seen, variabilities exist between each method, between both technicians, and within each method. The difference between the cup analyzer and the other methods is shown in the last columns. The greatest difference exists for the high a_w Colby cheese where the a_w measured by the cup analyzer was far below the values found by the other two methods.

The results presented in Table 7 show that the VPM method gives lower values than the Fett-Vos or Abbeon cup device. However, additional variability can be observed which is due to two technicians. Analysis of variance in Table 8 also shows that there is significant interaction between products and methods used to measure a_w. This means that the measured a_w of a given product depends on the method used. This is in agreement with the results presented before and shows that to obtain an accurate and reproducible measurement of a_w with the cup device, many precautions must be taken into account.

Table 7. a_w values for food items

Technician	Fett-Vos A	Fett-Vos B	VPM A	VPM B	Abbeon Cup Analyzer A	Abbeon Cup Analyzer B	Average Difference of Abbeon Cup Analyzer from Fett-Vos	Average Difference of Abbeon Cup Analyzer from VPM
Parmesan	.777	.762	.724	.757	.778	.778		
	.757	.742	.748	.747	.768	.768		
	.752	.762	—	—	.762	.768		
	.780	.730	—	—	.770	.768		
Avg	0.77	0.75	0.74	0.75	0.77	0.77	+0.01	+0.02
Swedish	.887	.890	.885	.900	.868	.876		
whey	.902	.890	.862	.903	.862	.880		
(cheese)	.898	.890	—	—	—	.910		
	.892	.890	—	—	—	.910		
	.877	—	—	—	—	—		
	.880	—	—	—	—	—		
	.875	—	—	—	—	—		
	.875	—	—	—	—	—		
Avg	0.89	0.89	0.87	0.90	0.87	0.89	−0.01	+0.01
Colby	.970	.990	.962	.992	.922	.918		
cheese	.965	.990	.973	.992	.922	.915		
	—	.998	—	—	—	.913		
	—	.998	—	—	—	.922		
Avg	0.97	0.99	0.97	0.99	0.92	0.92	−0.06	−0.06
Special	.885	.848	.876	.836	.873	.838		
Cuts	.877	.842	.835	.844	.873	.838		
	.873	.862	—	—	—	.860		
	.872	.858	—	—	—	.868		
Avg	0.88	0.85	0.86	0.84	0.87	0.85	−0.01	+0.01
Tender	.875	.912	.900	.888	.888	.901		
Vittles	.874	.902	.861	.892	.884	.901		
	.902	.908	.861	—	.928	.896		
	.903	.920	—	—	.926	.896		
Avg	0.89	0.91	0.88	0.89	0.91	0.90	+0.01	+0.02
	*	*						
Beef Tricks	.675	.624	.703	.745	.730	.708		
	.652	.624	.735	.710	.650	.678		
	.730	.614	—	—	—	.686		
	.718	.614	—	—	—	.694		
Avg	0.69	0.62	0.72	0.73	0.69	0.69	+0.02	−0.03

*Out of range of use
A, B indicates two technicians

Table 8. Analysis of variance: a_w values for food items in comparative study

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	$F^{0.05}$ Table
Between products	0.13049600	4	0.03262400	308.74	3.48
Between methods	0.00072400	2	0.00036200	3.43	4.10
Between technicians	0.00161033	5	0.00032207	3.05	3.33
Interaction product method	0.00592800	8	0.00074100	7.01	3.07
Analytical error	0.00105667	10	0.00010567	—	—
TOTAL	0.13981500	29			

CONCLUSIONS

Generally, it can be stated that there is not much statistical difference between a_w values obtained by the Fett-Vos procedure and the Abbeon cup device. However, the VPM method gives a significantly different a_w. Comparing the reproducibility of the methods it can be seen that the VPM is most reproducible while reproducibility of the Fett-Vos and the Abbeon device is approximately the same.

There is a question why the VPM method gives a lower a_w than the two other methods. Since the reproducibility of the VPM method is high, such parameters as room temperature fluctuations during measurement, skill and the psychic state of the technician, cannot be responsible for the observed differences between methods. Therefore, the difference must arise from a property which is inherent in the VPM method, and was not controlled during the study. It seems reasonable to postulate that in all three methods evaporation of water from the sample lowers the temperature of the sample. The Fett-Vos and the Abbeon device require a long time for equilibration, which allows the sample to attain room temperature. On the other hand, the VPM method requires less than one hour to obtain a constant reading of the manometer. This time might not be sufficient for the sample to reach room temperature, and hence the manometer reading divided by water vapor pressure read at room temperature would give a lower value of a_w than for water vapor pressure read at the sample temperature. It can be easily calculated that a difference between room temperature and the sample temperature of 1°C gives a difference of 0.038 a_w units at a_w = 0.6 and 0.057 a_w at a_w = 0.9. This could easily explain the lower values but since the VPM was not outfitted with internal thermocouples at the time of this study, the effect could not be measured.

The amount of water evaporated from the sample during the measurement is dependent on the a_w of the material examined. At low a_w a smaller amount of water is evaporated and a shorter equilibration time should be expected. Therefore, the lack of equilibrium between sample temperature and room temperature should affect the VPM reading in the manner dependent on the water content of the sample. Thus as expected, the variance for Special Cuts is twice as big as variance for Parmesan cheese which is at a lower a_w.

The Abbeon cup device could be a useful quality control tool for high a_w foods. The following points should be taken into consideration in using this analyzer.

(1) *Sensitivity to temperature.* If the sample to be measured is cooler than room temperature it will take longer than three hours for the indicator to come to equilibrium. The equipment brochure is based on testing at constant temperature for the full three hour equilibration period.

(2) *Length of equilibration period.* At high a_w's a longer period than three hours is needed for meat products. This may be because it takes longer for the water to diffuse out of foods as compared to salt solutions. In addition, the device should be exposed to a dry atmosphere between each measurement to dry the filament so as to prevent a hysteresis effect.

(3) Leaving the sensor in contact with vapor containing volatile glycols for long equilibration periods may damage its sensitivity if any are permanently adsorbed.

(4) *Calibration.* Calibration once a week is recommended by the manufacturer. However, when using the analyzer on a sample once or twice every day the readings were found to be significantly higher after three or four days. Calibration should be done therefore, every third day with at least an overnight drying time over desiccant, after calibration.

(5) Any material (salt solution of food matter, even when completely dry) allowed to remain on the metal plate between the sensor and the sample rendered the analyzer completely inoperable. However, simply cleaning this plate made the analyzer operable again. Extreme care must be taken that nothing is allowed to enter the holes and come in contact with the filament itself or any part inside that could not be cleaned.

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STORAGE STABILITY OF THIAMIN AND RIBOFLAVIN IN A DEHYDRATED FOOD SYSTEM[1]

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ABSTRACT

The storage stability of thiamin mononitrate and riboflavin in a low moisture dehydrated model food system was determined as a function of water activity, moisture content and storage temperature. Fortification of the model system was at a level of 25% *RDA per* 100 *g. The model system was equilibrated at water activities below, at and above the calculated water activity corresponding to the monomolecular moisture content for the adsorption isotherms. Thiamin retention was approximately* 100% *after eight months storage at temperatures from* 20–37°*C and* a_w 0.1 *to* 0.65. *Retention of thiamin in the model food system was only* 10–20% *at* 45°*C with an* a_w *from* 0.40–0.65. *Riboflavin retention was approximately* 100% *after eight months storage at* 10 *to* 20°*C with an* a_w *of* 0.1 *to* 0.65 *and at* 30°*C, with an* a_w *of* 0.1 *to* 0.40. *At* 37°*C the loss of riboflavin increased with increasing water activity. The rate of riboflavin destruction dramatically increased in the model system packaged in an oxygen permeable container. A similar effect was not observed in the thiamin study. The stability of thiamin and riboflavin was unaffected by the addition of vitamins A or C.*

INTRODUCTION

The chemical, microbiological and nutrient quality of foods during storage have been shown to be dependent upon storage temperature, oxygen, light, moisture content and physio-chemical state of water. Farrer (1955) and more recently Dwivedi and Arnold (1973) have reviewed the factors relating to the thermal destruction of thiamin. Kinetically, thiamin destruction due to heating can be described by the Arrhenius equation and is affected by pH, oxygen, trace metals and the

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form of the thiamin molecule. Hollenbeck and Obermeyer (1952) reported that thiamin mononitrate exhibited greater storage stability than thiamin chloride hydrochloride in enriched flour. Both thiamin salts were subject to increased degradation with increasing moisture content. The deleterious effect of increasing moisture content on thiamin stability has also been reported by Nymon and Gortner (1948) and Bookwalter *et al.* (1968).

Riboflavin is considered more heat stable than thiamin, but highly sensitive to degradation by light. The storage stability of riboflavin in dry products is excellent if protected from light (Borenstein 1971). Unfortunately, little data on the storage stability of riboflavin in dehydrated food systems at specified conditions of moisture content and temperature are available.

Previously, we have reported on the stability of ascorbic acid in a dehydrated model food system (Kirk *et al.* 1977). This paper is a continuation of our investigation of the parameters affecting micronutrient stability in dehydrated low moisture model food systems. The specific goals being: a) to generate kinetic data for the degradation of thiamin and riboflavin as a function of water activity, moisture content and storage temperature in a low moisture dehydrated food system; b) to determine the relative importance of each parameter to the stability of each micronutrient; and c) to determine the effects of other micronutrients, namely vitamins A and C, on the storage stability of thiamin and riboflavin in a low moisture dehydrated food system.

EXPERIMENTAL

Model System

A model food, pH 6.8 (Table 1), designed to simulate the composition of a ready-to-eat breakfast cereal was prepared as previously reported (Kirk *et al.* 1977). Three model systems were prepared and fortified with 1) vitamin B_1—thiamin mononitrate; 2) vitamins A, B_1 and C; and 3) vitamins A, B_2 and C, at a level of 25% NAS/NRC RDA per 100 g (dry weight basis) for each vitamin.

Cereal Samples

Three commercially prepared cereals (one corn and two oat based) were obtained from General Foods Corporation, Post Division. Each cereal had been fortified with vitamins A and B_2. Both of the oat based cereals were identical with the exception that one was fortified with folic acid in addition to vitamins A and B_2.

Table 1. Composition of model food system

Component	%[d]
Protein[a]	10.2
Fat	1.0
Carbohydrate[b]	76.5
Reducing Sugar[c]	5.1
Sucrose	5.1
Salt	2.0
Water	variable

[a]Soya protein—Promine E, Central Soya
[b]Food Grade Powdered Starch—A. E. Staley, Inc., and Corn Sirup Solids 15 D.E., American Maize
[c]Supplied by the corn syrup solids % dry weight basis
[d]Calculated on dry weight basis

Equilibration and Packaging

Equilibrium moisture content isotherms were determined for the freeze-dried model system at 10, 20, 30 and 37°C according to the method of Palnitkar and Heldman (1971). Measurements were determined in a closed system using a Cahn electrobalance and free water surfaces which were maintained at the appropriate temperature to give desired water vapor pressures.

The samples for storage studies were adjusted to water activities of 0.10, 0.24, 0.40, 0.50 and 0.65 on the adsorption leg of the sorption hysteresis curve by placing thin slabs of freeze-dried model system or the dried cereal into an equilibration chamber and forcing conditioned air provided by an Aminco-Aire unit through the closed system. When water activities were required which were lower than could be provided by the Aminco-Aire unit alone a dehumidifier and cooling coils were placed in the closed system to further reduce the relative humidity of the equilibrating air. Immediately after equilibration, the samples were packaged in 208 × 006 thermal death time (TDT) cans (~15 g) and stored at the appropriate storage temperature to prevent any shift in a_w.

Unequilibrated model system and cereal samples were also packaged in three-fourth ounce commercial paperboard breakfast cereal boxes (3 cm × 7 cm × 10.3 cm) containing waxed liners (thickness 0.009 cm) immediately after freeze drying. Moisture transfer coefficient for the liner and box plus liner were equal (7.25×10^{-5} g H_2O-cm/m^2-h-mmHg). These samples were stored in 10, 40 and 85% RH controlled

atmosphere cubicles at 30°C in order to study the effects of moisture vapor and oxygen transmission on the rate of thiamin and riboflavin destruction.

Stability studies for thiamin and riboflavin in the model system and cereals packaged in TDT cans were carried out at 20, 30, 37, 45°C and 10, 20, 30 and 37°C, respectively.

Moisture Content Measurement

Moisture content (dry weight basis) of equilibrated model system was determined by drying the samples in a vacuum oven at a vacuum of 28 inches Hg at the same temperature at which the product had been equilibrated. A temperature differential was maintained to aid in the transfer of moisture from the product by inserting a dry ice-acetone cold trap between the vacuum oven and the vacuum pump. Air, dried by bubbling through concentrated H_2SO_4, was admitted into the vacuum oven at a rate of 15–20 ml/min to aid in the displacement of water vapor from the drying chamber. All samples were dried until they reached constant weight. Use of this method for the determination of the moisture content permitted the determination of the water activity to ensure that it had not changed during storage.

Vitamin Determination

Thiamin and riboflavin were determined by the respective automated fluorometric procedures described by Kirk (1975a,b). Vitamin levels for zero time storage were determined after each sample was equilibrated to the desired water activity. Analyses were performed at monthly intervals for the duration of the eight month storage study.

Data Analysis

The loss of thiamin and riboflavin was treated as a first order function.

RESULTS AND DISCUSSION

Thiamin Stability

The influence of water activity and storage temperature on the stability of thiamin mononitrate in a dehydrated model food system packaged in TDT cans and stored for 8 months is shown in Fig. 1. After eight months storage, destruction of thiamin was less than 5% at storage

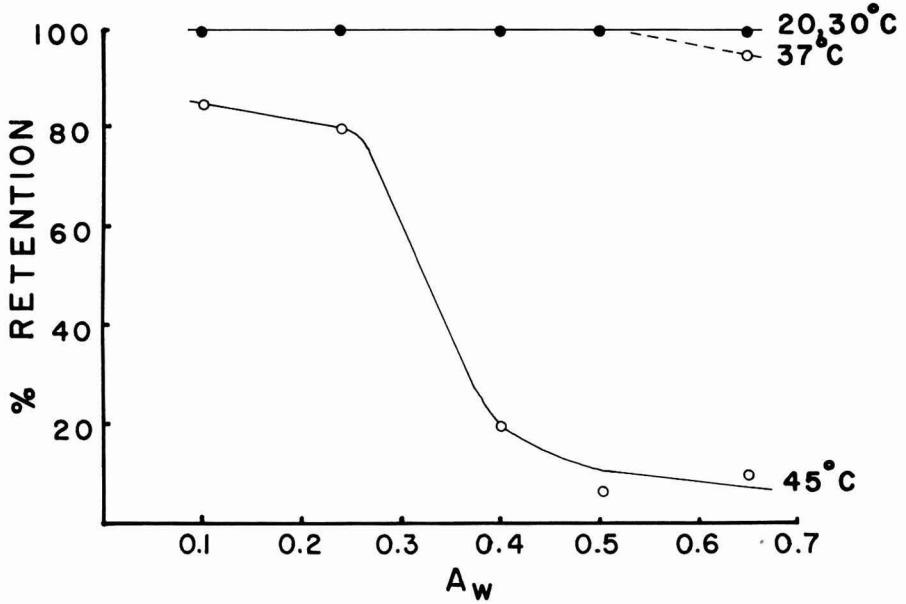

FIG. 1. THIAMIN RETENTION IN MODEL SYSTEM PACKAGED IN TDT CANS AS A FUNCTION OF WATER ACTIVITY AT SELECTED STORAGE TEMPERATURES AFTER 8 MONTHS STORAGE

temperatures $\leqslant 37°C$ and was independent of water activity at $a_w \leqslant 0.65$. Under these storage conditions, the first-order rate constants describing thiamin losses were very small ($k < 0.1 \times 10^{-3}$ days^{-1}) with large standard deviations and correlation coefficients <0.90. Attempts to treat the thiamin destruction data by other kinetic functions did not reveal a better fit. Thus, at storage temperatures $\leqslant 37°C$ and a_w's $\leqslant 0.65$, thiamin mononitrate was found to be very stable in the dehydrated model food system packaged in TDT cans.

Data from Table 2 and Fig. 1 show that a significant rate of thiamin loss occurred in the model system stored at 45°C. As shown in Fig. 1, a significant increase in the rate of destruction occurred when the a_w of the dehydrated model food system exceeded the monomolecular moisture content ($a_w = 0.24$) as would be expected (Labuza *et al.* 1970). At water activities greater than 0.24 and storage temperatures of 45°C, where destruction of thiamin mononitrate was maximum, browning of the dehydrated model system was very pronounced. These data support the findings of Van der Poel (1956) and Lhoest (1957), who reported that thiamin reacts strongly in a Maillard-type browning reaction in dry or aqueous products when heated and may be an important

Table 2. Rate constants and half-lives for thiamin degradation in model system fortified with thiamin and thiamin, ascorbic acid and vitamin A at 45°C as a function of water activity packaged in TDT cans

	B_1 Model System			A, B_1, C Model System		
a_w	k[a]	σ[b]	$t_{1/2}$[c]	k[a]	σ	$t_{1/2}$[c]
0.10	0.66	0.77	1050	0.14	0.71	4900
0.24	0.91	0.50	762	0.65	0.65	1066
0.40	6.75	1.20	103	6.48	1.75	107
0.50	11.01	2.08	63	9.27	1.73	75
0.65	8.67	1.69	80	9.48	1.84	73

[a]First-order rate constant, $k \times 10^{-3}$ days^{-1}
[b]Standard deviation, $\sigma \times 10^{-3}$
[c]Half-life, days

factor in the loss of thiamin during processing and storage. Data from these studies are further supported by the results of Hollenbeck and Obermeyer (1952), who reported no significant loss of thiamin mononitrate in flour containing 9–14% moisture and stored at 25°C, but at a storage temperature of 38°C destruction of thiamin increased with increasing moisture content.

The data for the stability of thiamin mononitrate at 45°C in the multi-vitamin fortified model system are presented in Table 2. Above the monomolecular moisture content (0.24 a_w), statistical analyses showed no significant difference between the thiamin destruction rates for the single and multi-vitamin fortified model systems packaged in TDT cans. Data obtained for the rate of thiamin destruction in model system stored at 20, 30 and 37°C indicated there was no significant difference in the stability of thiamin in the thiamin and multi-vitamin fortified model systems.

Dehydrated model food system fortified with thiamin only, and thiamin, ascorbic acid and vitamin A were packaged without equilibration in paperboard boxes in order to determine the effect of moisture vapor and oxygen transmission on the stability of thiamin mononitrate during storage. The boxed samples were stored at 30°C at constant relative humidities of 10 and 40%. Under these storage conditions moisture vapor equilibrium was achieved in approximately four weeks (Purwadaria *et al.* 1976). The loss of thiamin in the boxed samples was less than 2% (Table 3), which is similar to that observed in TDT cans and stored under similar conditions. The rate constant describing thiamin destruction in the boxed model system was less than 1×10^{-3} days^{-1} for all storage conditions. These data suggest that the

Table 3. Thiamin loss (%) in model food system packaged in paperboard boxes after eight months storage at constant relative humidity at 30°C

% RH	B_1 Model System	A, B_1, C Model System
10	<2%	<2%
40	<2%	<2%

stability of thiamin mononitrate in low moisture dehydrated foods at storage temperatures ≤30°C was not dependent upon water activity, oxygen content and water vapor transmission.

Riboflavin Stability

Experimental data describing the stability of riboflavin in a multivitamin fortified dehydrated model system equilibrated at 0.1–0.65 a_w and stored in TDT cans at 10, 20, 30 and 37°C are presented in Fig. 2. The rate constants describing the loss of riboflavin in the model system packaged in TDT cans and stored at 10, 20 and 30°C and 0.10–0.65 a_w are quite small ($k < 2 \times 10^{-3}$ days^{-1}) with large standard deviations and correlation coefficients less than 0.90. As found for thiamin, no better fit of the data describing riboflavin losses was obtained with other rate functions. Thus, for model system packaged in TDT cans at $a_w \leq 0.65$ and stored at temperatures ≤30°C, the experimental data suggests excellent riboflavin stability during storage. At 37°C storage temperature, riboflavin did exhibit decreasing stability with increasing water activity (Table 4 and Fig. 2), however, the change was not as dramatic as it was for thiamin above the monolayer moisture content. The stability of riboflavin in the model system fortified only with riboflavin was not studied in view of its stability in the multifortified model system.

Stability studies for the multi-vitamin fortified dehydrated model system packaged in paperboard boxes and stored at 30°C in 10, 40 and 85% RH controlled atmosphere cubicles (Table 5) showed that the half lives for riboflavin destruction were much less than those found for the model systems packaged in TDT cans at lower humidities (Table 4). These data suggest the involvement of dissolved oxygen in the destruction of riboflavin. Calculation of the maximum number of

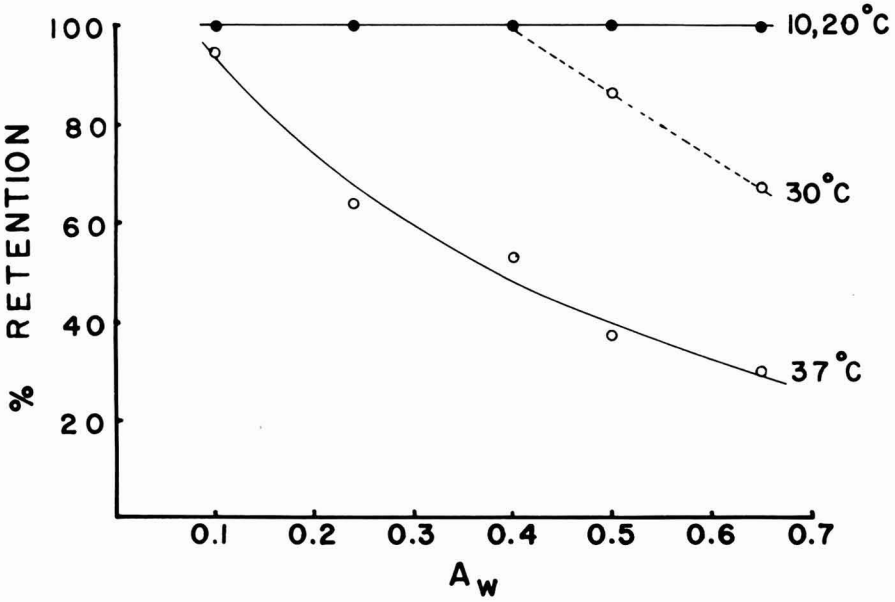

FIG. 2. RIBOFLAVIN RETENTION IN MODEL SYSTEM PACKAGED IN TDT CANS AS A FUNCTION OF WATER ACTIVITY AT SELECTED STORAGE TEMPERATURES AFTER 8 MONTHS STORAGE

Table 4. Rate constants and half-lives for riboflavin degradation in model system at 37°C as a function of water activity packaged in TDT cans

	A, B_2, C Model System		
a^w	k^a	σ^b	$t_{1/2}{}^c$
0.10	0.23	1.55	3013
0.24	1.88	1.68	369
0.40	2.63	2.11	264
0.50	4.11	1.97	169
0.65	5.03	2.25	138

[a]First-order rate constant, $k \times 10^{-3}$ days^{-1}
[b]Standard deviation, $\sigma \times 10^{-3}$
[c]Half-life, days

moles of dissolved oxygen that could be present in the model food system yielded 4.4×10^{-7} moles O_2/cm^3 water, compared with 1.3×10^{-7} moles vitamin B_2/cm^3 water. The moles of gaseous oxygen present in the TDT can will vary as a function of the inter- and intra-

Table 5. Rate constants and half-lives for riboflavin degradation in model system packaged in paperboard boxes after eight months storage at constant relative humidity at 30°C

% RH	A, B_2, C Model System		
	k[a]	σ[b]	$t_{1/2}$[c]
10	4.4	2.1	158
40	4.3	2.3	161
85	4.3	2.7	161

[a]First-order rate constant, $k \times 10^{-3}$ days^{-1}
[b]Standard deviation, $\sigma \times 10^{-3}$
[c]Half-life, days

stitial spaces of the packaged model system. Using estimates that 20 to 40% of the total volume of the TDT can could be occupied by air, the moles of gaseous oxygen would range from 2.8×10^{-5} to 5.4×10^{-5}. This would represent a 100-fold excess of moles of gaseous oxygen/mole of riboflavin initially available in the TDT cans. Because ascorbic acid is present in the model system (6×10^{-6} moles/cm^3 water), the dissolved oxygen in the model system should be preferentially consumed by the rapid oxidation of ascorbic acid and, therefore, not readily available for riboflavin destruction (Kirk *et al.* 1977). The extent to which gaseous oxygen can effect the rate of loss of riboflavin would be a function of the rate of its dissolution into the dehydrated system and the oxidation of remaining ascorbic acid.

In the boxed multi-vitamin fortified model system, initially there is a three to one molar ratio of dissolved oxygen to riboflavin. This ratio could increase due to the permeability of the container to oxygen and the decrease in riboflavin content.

No significant influence of increasing relative humidity was observed on the stability of riboflavin in the model system stored in paperboard boxes. This would be expected in view of the large excess of dissolved oxygen to riboflavin at each relative humidity. The rate of oxygen dissolution as a function of various product and storage parameters is under investigation.

Evaluation of riboflavin storage stability data for commercially prepared cereal products stored for 8 months at 10, 20, 30 and 37°C in TDT cans at a_w's of 0.24, 0.40 and 0.65 showed it to be similar to that observed for the model system ($k = 1 \times 10^{-3}$ days^{-1}; Fig. 3) stored at 10 and 20°C (Fig. 2). The presence of folic acid in the oat based cereal

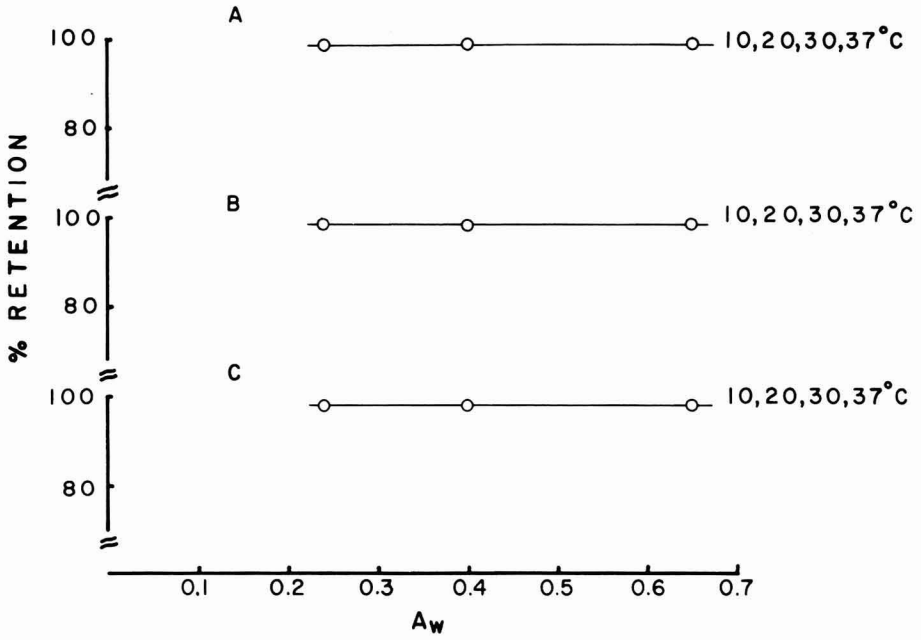

FIG. 3. RIBOFLAVIN RETENTION IN BREAKFAST CEREALS PACKAGED IN TDT CANS AS A FUNCTION OF WATER ACTIVITY AT SELECTED STORAGE TEMPERATURES AFTER 8 MONTHS STORAGE: A) CORN, B) OAT WITHOUT FOLIC ACID, AND C) OAT WITH FOLIC ACID

showed no apparent effect on riboflavin stability. Cereals packaged in paperboard boxes at 30°C and 10, 40 and 85% RH demonstrated a 2–3 fold increase in riboflavin stability compared to the model system stored under similar conditions (Table 6). The increased stability of riboflavin in cereals at 30 and 37°C in TDT cans and at all conditions in the paperboard boxes is believed to reflect the presence of antioxidants in the cereal products as well as other factors.

CONCLUSIONS

The storage stability of thiamin and riboflavin in a low moisture dehydrated model food system as a function of water activity, moisture content, storage temperature and oxygen was investigated. Thiamin was found to be stable at storage temperatures $\leqslant 37°C$ at a_w's from 0.10 to 0.65. At a storage temperature of 45°C the rate of thiamin loss was significantly higher, showing about 80 to 90% loss in model system with water activities above the monomolecular moisture content (0.24) after 8 months of storage.

Table 6. Riboflavin loss (%) in model food system and commercial cereals packaged in paperboard boxes after eight months storage at constant relative humidity and 30°C

% RH	Multi-Vitamin Fortified Model System	Breakfast Cereals Fortified with Vitamin A, B_2		
		Corn	Oat[a]	Oat[b]
10	65	21	<5	<5
40	64	21	<5	<5
85	64	36	<5	<5

[a]Oat based cereal without folic acid
[b]Oat based cereal with added folic acid

Riboflavin losses were shown to be minimal in both food systems at storage temperatures ≤30°C and water activities ≤0.65. However, at 37°C riboflavin losses increased with increased water activity. The stability of riboflavin in the model system packaged in paperboard boxes, which contains a factor of 3 more moles of oxygen than riboflavin, was greatly reduced. A comparable reduction in riboflavin stability was not apparent in the ready-to-eat breakfast cereals packaged in paperboard boxes, which indicates the involvement of some component in the cereals increasing the stability of riboflavin.

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EVALUATION OF TOMATO CONDITION IN BIN LOADS OF PROCESSING TOMATOES HARVESTED AT DIFFERENT LEVELS OF RIPENESS

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ABSTRACT

*VF*145-7879 *variety of tomatoes were commercially machine harvested at three maturity levels which were* 12 *days and* 7 *days before the field was to be customarily harvested, and again when the field was harvested for delivery to the processor. The effects of transportation, storage and a simulated commercial wash were measured in terms of wholeness, several degrees of damage, and loss by weight for each of the maturity levels. Tomatoes harvested at the regular time showed greater losses and deterioration of condition than those harvested earlier. The percentage of tomatoes with visible locules (exposed seed cavity) determined before washing was found to be a useful measure for predicting the percentage weight loss through washing. The percentages of tomatoes with visible locules measured after washing were found to be indicators of the condition of VF*145-7879 *tomatoes for processing.*

INTRODUCTION

Tomato fruit condition following mechanical harvesting, transportation, and the inevitable delay before processing is of utmost economic importance to the processor. Very few studies have been made to document how these procedures alter the condition of the fruit for processing as they relate to once-over harvesting at different stages of maturity. Splits in the tomatoes exposing locular material (visible locules) are nonexistent in the field under normal growing conditions. On the other hand, fruits with visible locules make up a large percentage of the deliveries when a soft-textured round type of tomato like the

[1] Deceased

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VF145-7879 undergoes the customary harvesting procedures. This study was undertaken to determine whether this status could be altered by harvesting earlier when the texture of the fruit was firmer.

Previous tests indicated that both damage and losses could be greatly reduced by an earlier harvest. Most of these tests on tomato damage, however, were carried out in model systems, under noncommercial conditions. In this study, tomato condition and the subsequent losses from harvest through a commercial washing procedure were measured when tomatoes were commercially machine harvested into bins, at three levels of maturity and after three periods of storage.

MATERIALS AND METHODS

Harvesting

VF145-7879 variety of tomatoes, predominant in California, were machine harvested with a U. C. Blackwelder harvester at the rate of 3–4 acres per day. Harvesting was scheduled with growers to obtain replicate loads 12 days and 7 days earlier than a grower customarily harvested his fields for the processor, as well as during customary harvest. The ratio of percent grass green to percent deliverable tomatoes presently used by field representatives and other members of the tomato industry to define field maturity was not determined in this study. It may be estimated however, using relationships developed in another study (Leonard *et al.* 1970). The estimated field maturities would be 14% grass green to 86% deliverable for the 12 days early lots; 9% grass green to 91% deliverable for 7 days early lots, and 2% grass green to 98% deliverable for the customary harvests. To comply with commercial practice, the tomatoes were sorted on the harvester to discard the green and defective fruits to make each lot meet State requirements for a commercial delivery. They were then filled into 48 × 48 × 24 in. plain wood bins so that each contained approximately 1000 lb of tomatoes. The bins for this study were lined with plastic to prevent loss of liquid prior to weighing and subsequent washing and sorting. One-third of the number of the bins from each delivery was examined on arrival at the laboratory, while the remaining two thirds were stored under ambient conditions 24 and 48 hr, respectively. For evaluating the influence of transportation, a set of bins from certain deliveries was given 100 miles of simulated transportation on a device designed by O'Brien *et al.* (1963), before any storage or examination of tomato condition was undertaken.

Bins 48 × 48 × 48 in. in dimension were included as a secondary

phase of the study. Fruit harvested when the grower was conducting his harvest for delivery to the processor was used in these trials. A comparison of the 24 in. bin and the 48 in. bin was made in duplicate.

Sampling

The bins were weighed on arrival at the laboratory and were sampled by removing a 12 in. diameter core of tomatoes from top to bottom through a sampling tube placed on top of the harvested tomatoes approximately 12 in. away from the sides. Sampling was repeated at the end of each storage period. These samples contained about 50 lb of tomatoes and were used to obtain analytical information on the tomatoes prior to washing. The remaining tomatoes were washed and classified by trained personnel into the classes listed below as they travelled along an endless belt, for the purpose of determining their physical condition. Tomatoes in each classification were weighed and the composition based on harvested weight in terms of percent by weight was calculated. Tomatoes from each classification were recombined in these percentages for laboratory analyses.

Physical Classifications

Tomato condition was subjectively determined using a system of definitions compiled for the purposes of this research by a committee of representatives from processors, growers and State grading personnel. The definitions are as follow.

(1) Peelable Tomatoes. Well-colored, whole tomatoes, larger than 1½ in. diameter, with the round, characteristic shape of the variety. The tomatoes had to be firm and free from scars and defects. The skins had to be unbroken. A green or yellow area less than 3/4 in. diameter was permitted, only if centered on the stem end.

(2) Peelable Tomatoes with Less than One Inch Cracks. Defined the same as No. 1 but permitted minor breaks in the skin totalling not more than one inch in length.

(3) Peelable Tomatoes with Greater than One Inch Cracks. Defined the same as No. 1 but permitted breaks in the skin totalling more than one inch. Breaks in the flesh were not allowed in either this or the No. 2 category.

(4) Product Tomatoes. Undamaged tomatoes that were well-colored and/or fairly well-colored, smaller than 1½ in. in diameter, or odd shaped, or with green and yellow areas not centered on the stem end. These green and yellow areas were permitted up to 1½ in. in diameter if they did not require removal of more than 25% of the tomato.

(5) Product Tomatoes with Less than One Inch Cracks. Defined the same as No. 4 but permitted minor breaks in the skin totalling not more than one inch in length.

(6) Product Tomatoes with More than One Inch Cracks. Defined the same as No. 4 but permitted breaks in the skin totalling more than one inch, as in No. 3.

(7) Crushed Tomatoes. Tomatoes which were crushed to the point of misshaping the fruit, and the damage extended into the flesh, but were usable for product.

(8) Visible Locules. Tomatoes in which the skin and flesh were broken through, exposing one or more of the seed cavities, but were usable for product.

(9) Bruised. Tomatoes which were bruised, displaying loose skin and a soft, mushy condition in corresponding areas, but were usable for product. This classification was distinctly different from overripe, commonly called "waterbag," or sunscalded tomatoes.

(10) Green. Tomatoes which did not meet the minimum color requirement or had green or yellow areas which required removal of more than 25% of the tomato.

(11) Natural Defects. Tomatoes which had mold, worm and/or extensive sun damage.

Chemical Analyses

Total solids, soluble solids, pH and titratable acidity were determined using the methods of AOAC (1970). The solids and acidity are reported as percentages by weight.

Serum viscosity was determined using the following procedure:

A weighed sample of tomatoes was heated in a microwave oven to inactivate the pectic enzymes. The evaporation loss was restored after the samples were cooled. They were then pulped through an 0.027 in. screen using a laboratory pulper. About 250 ml of the resulting juice was centrifuged at 2000 rpm for 15 min. The serum was first filtered through Whatman 90 filter paper and then through a Gelman type E glass fiber filter using a syringe to transfer it directly into an Ostwald-Cannon-Fenske size 100 viscometer. Flow time was measured at constant 30°C. If replicates did not check within 0.4 sec the determination was repeated. Results are reported in centistokes (cs), where

$$cs = \text{flow time (sec.)} \times k \text{ (calibration constant of viscometer)}$$

RESULTS AND DISCUSSION

The data accumulated to determine physical condition of the various harvest lots were grouped for this report into fruits that were suitable for peeling (classes 1, 2, and 3), undamaged tomatoes (classes 1, and 4), and tomatoes with major damage (classes 7, 8, and 9). Tomatoes with visible locules (class 8) was the only class treated separately for reasons that will be explained later. Data for the various lots in each harvest category were treated statistically and it is these data which are presented in tabular or graphical forms.

Reductions in the percentage of tomatoes suitable for peeling reflected the overall condition and the losses in weight that occurred during washing. The usefulness of these tomatoes in indicating overall condition, however, is limited because the occurrence of tomatoes suitable for peeling will depend more on the prevailing climatic conditions and the type of cultural treatment used during growth than on harvesting practices, length of transportation, and storage. Tables 1 and 2 show that the amount of peelers was rather small for the lots studied, yet the relative influences of maturity, the time of storage after harvesting, and bin depth were quite apparent. The longer harvesting was delayed and the longer the tomatoes were stored before washing prior to processing, the greater was the decrease in the percentage of tomatoes suitable for peeling. Tomatoes harvested 12 or 7 days early suffered less damage than did the tomatoes harvested at the customary time for commercial delivery.

Container design limits the maximum fill of tomatoes to about 24 in. in bulk bins and 48 in. in bulk truck loads. The results of evaluating bins filled 24 and 48 in. deep are given in Table 2. Paired comparison of the results indicated that the 24 in. fill retained significantly more peelers and undamaged tomatoes than the 48 in. fill. Both losses and visible locules were higher in the 48 in. fill. The results update the findings of Ries and Stout (1962) and O'Brien *et al.* (1963), showing that the depth of fill significantly influences tomato condition.

Some storage or delay from harvesting to processing is inevitable under commercial operating conditions. However, as the data indicate, by harvesting 12 or 7 days early the tomatoes were more resistant to damaging and remained in a significantly better condition through storage. The data on undamaged tomatoes as influenced by storage and maturity are shown in Fig. 1. In loads harvested at the regular time, the decreases in the amount of undamaged tomatoes were significant ($p < 0.05$) through each 24 hr storage period. For the 7 days early harvest, the decrease was significant only through the first 24 hr storage, after which further change in the amount of undamaged tomatoes was not

Table 1. Evaluation of tomato condition after washing as affected by early harvest (average value ± one standard deviation)

Percentage of Harvested Weight	12 Days Early	7 Days Early	Regular Harvest
	Tomato condition within 4 hr of harvesting		
% Peelable tomatoes[1]	14.2 ± 0.1a[4]	9.6 ± 3.1ab	4.9 ± 1.5b
% Undamaged tomatoes[2]	85.8 ± 0.5a	61.3 ± 5.8b	42.8 ± 14.7c
% Tomatoes with major damage[3]	8.9 ± 2.1a	20.1 ± 2.6b	29.5 ± 7.8c
% Tomatoes with visible locules	2.3 ± 0.3a	5.2 ± 2.8a	15.1 ± 6.3b
% Weight loss through washing	1.5 ± 1.0	2.4 ± 1.3	3.6 ± 3.3
	Tomato condition 24 hr after harvesting		
% Peelable tomatoes[1]	9.5 ± 1.3	7.3 ± 3.7	3.1 ± 0.6
% Undamaged tomatoes[2]	77.1 ± 4.5a	51.1 ± 4.8b	32.9 ± 10.7c
% Tomatoes with major damage[3]	15.0 ± 4.1a	34.5 ± 3.6b	41.3 ± 10.1b
% Tomatoes with visible locules	4.8 ± 2.5a	7.9 ± 2.4a	26.6 ± 7.6b
% Weight loss through washing	4.1 ± 1.0	3.9 ± 0.4	6.9 ± 2.5
	Tomato condition 48 hr after harvesting		
% Peelable tomatoes[1]	10.7 ± 4.1a	4.5 ± 2.9b	0.4 ± 0.3b
% Undamaged tomatoes[2]	77.4 ± 1.2a	44.7 ± 7.8b	6.1 ± 4.5c
% Tomatoes with major damage[3]	17.8 ± 0.2a	40.8 ± 5.9b	61.9 ± 4.5c
% Tomatoes with visible locules	4.2 ± 0.2a	11.6 ± 3.3a	45.8 ± 4.2b
% Weight loss through washing	2.2 ± 1.1a	7.4 ± 1.6a	28.9 ± 8.0b

[1] Includes peelable tomatoes with broken skin
[2] Includes undamaged peelable tomatoes
[3] Includes crushed, bruised and visible locules
[4] Values within a row which do not have a letter in common differ significantly, $p = 0.05$, comparing ripeness levels

Letter a designates best condition, c the worst

Table 2. Influence of fill depth in bins on the condition of processing tomatoes harvested at regular time (average value ± one standard deviation)

Percentage of Harvested Weight	Fill[1]	Time after Harvesting 4 hr	24 hr	48 hr
% Peelable tomatoes	24 in.[2]	6.1 ± 0.2	3.2 ± 0.7	0.5 ± 0.4
	48 in.	4.7 ± 0.4	2.0 ± 0.9	0.2 ± 0.3
% Undamaged tomatoes	24 in.[2]	55.8 ± 3.7	39.1 ± 0.1	7.7 ± 4.8
	48 in.	47.3 ± 1.0	25.5 ± 7.2	3.0 ± 2.7
% Tomatoes with major damage	24 in.	22.5 ± 2.1	35.5 ± 2.1	64.3 ± 2.8
	48 in.	31.5 ± 0.6	46.9 ± 8.1	60.2 ± 1.0
% Tomatoes with visible locules	24 in.	10.5 ± 0.3	22.3 ± 0.1	47.1 ± 5.0
	48 in.[2]	15.4 ± 2.8	33.1 ± 4.9	49.8 ± 2.4
% Weight loss through washing	24 in.	1.3 ± 0.0	5.5 ± 0.5	24.5 ± 3.5
	48 in.[2]	2.8 ± 1.8	8.8 ± 3.2	34.2 ± 4.4

[1] 24 in. fill is equivalent to the full depth of bins (1/2 ton units) and 48 in. fill of most bulk trucks (12 ton units)
[2] In paired test, significantly higher $p \leq 0.05$

significant. Loads harvested 12 days early showed the smallest changes and they were not statistically significant.

The data on visible locules as influenced by storage and maturity are shown in Fig. 2. For all maturities, percentages of tomatoes with visible locules increased with storage, but the increase was less when the tomatoes were harvested earlier than at the regular time.

Tomatoes harvested early were consistently less susceptible to damage caused by the 100 miles of simulated transportation. The average decrease in the percentage of undamaged tomatoes recovered (4.6 ± 5.9) was significant ($p < 0.1$) in the loads harvested at the regular time but not in loads that were harvested early (1.2 ± 3.1). The average increase in the percentage of tomatoes with visible locules caused by simulated transportation (3.9 ± 3.5) was also significant ($p < 0.05$) in the regular but not in the earlier harvested loads (0.9 ± 1.9).

Chemical data on tomatoes harvested at different maturities and changes in composition that occurred through storage are given in Table 3. These data are average values for several harvest lots, however, the pattern of changes in composition is not as clear-cut as might be expected. In general, the lots harvested earlier than customary appear to be lower in total solids, and pH, and higher in total acid and serum viscosity than the lots harvested by customary practice. These differences, however, are not statistically significant. The lots harvested 12 and 7 days early showed no statistically significant changes in composition through storage. The lots harvested at the regular time, on the

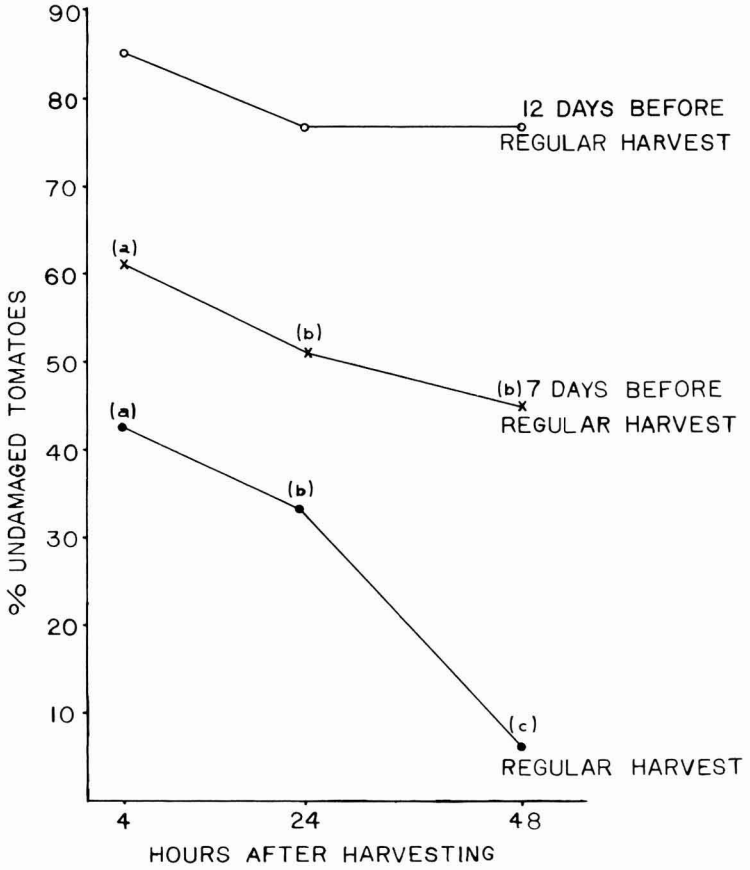

FIG. 1. INFLUENCES OF EARLY HARVESTING AND TIME IN STORAGE ON THE RECOVERY OF UNDAMAGED TOMATOES FOR PROCESSING

The letters indicate significant differences ($p < 0.05$) attributed to times of storage within each harvest lot.

other hand, underwent statistically significant changes in solids, serum viscosity, pH and titratable acidity. These changes reflect the physical breakdown of the tomatoes reported in Tables 1 and 2. The breakdown in physical structure caused marked lowering of the serum viscosity and a very significant increase in water insoluble solids. Both of these compositional factors are closely related to the quality and the yield of consistency-oriented products.

O'Brien (1974) reported that the percentage of visible locules ("Class III damage") determined after washing was usually less than that

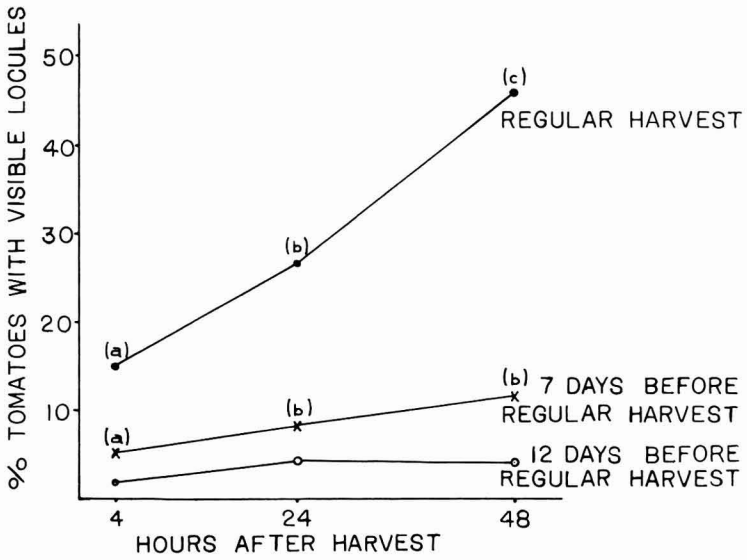

FIG. 2. INFLUENCES OF EARLY HARVESTING AND TIMES OF STORAGE ON THE OCCURRENCE OF VISIBLE LOCULES AFTER COMMERCIAL WASHING

The letters indicate significant differences ($p < 0.05$) attributed to times of storage within each harvest lot.

determined prior to washing. It is believed that the decrease was caused by the sampling procedure used in that study. In this study, we avoided the necessity of sampling after washing by subjecting the entire washed lots, 1½–2 tons, to physical classification. The percentage of tomatoes with visible locules was determined as a ratio of their weight to the total harvested weight of the lot. When the percentages of tomatoes with visible locules after washing were compared to the percentages found by the tube sampling procedure before washing, for 75 lots, statistically significant ($p < 0.001$) differences were found, averaging 4.8 ± 4.3. The relationship between the percentage of tomatoes with visible locules determined before and after washing was linear with a significant ($p < 0.001$) correlation coefficient $r = 0.74$, and is as follows:

$$y = 1.13\,x + 4.04$$

where x = % by wt visible locules in subsample before washing
y = % by wt visible locules after washing

The most striking finding of this study was the amount of tomato tissue and locular material lost through washing, as related to the time

Table 3. Influence of early harvest and time of storage on tomato solids, acidity, and serum viscosity (average value ± one standard deviation)

Storage Hours	Total Solids %	Soluble Solids %	Water Insoluble Solids % Dry Weight[1]	Serum Viscosity Centistokes	pH	Titratable Acidity %
			12 Days early			
4	5.44 ± 0.32	4.81 ± 0.20	11.45 ± 1.89	3.51 ± 0.10	4.17 ± 0.16	0.42 ± 0.05
24	5.33 ± 0.17	4.69 ± 0.19	11.97 ± 0.76	3.44 ± 0.50	4.29 ± 0.06	0.42 ± 0.04
48	5.43 ± 0.31	4.80 ± 0.27	11.64 ± 1.05	3.40 ± 0.16	4.24 ± 0.10	0.43 ± 0.06
			7 Days early			
4	5.74 ± 0.32	5.08 ± 0.38	11.48 ± 2.40	3.46 ± 0.77	4.27 ± 0.06	0.39 ± 0.03
24	5.68 ± 0.34	5.10 ± 0.32	10.17 ± 1.99	3.30 ± 0.47	4.40 ± 0.09	0.39 ± 0.05
48	5.96 ± 0.23	5.29 ± 0.32	11.18 ± 2.00	3.11 ± 0.75	4.34 ± 0.07	0.38 ± 0.03
			Regular harvest			
4	5.68 ± 0.44	5.08 ± 0.43	10.74 ± 1.04b[2]	3.26 ± 0.45a	4.36 ± 0.05a	0.35 ± 0.03a
24	5.70 ± 0.47	4.99 ± 0.42	12.46 ± 0.89a	3.09 ± 0.60a	4.44 ± 0.04b	0.33 ± 0.03a,b
48	5.78 ± 0.37	4.97 ± 0.36	13.94 ± 1.56a	2.11 ± 0.35b	4.47 ± 0.07b	0.32 ± 0.03b

[1] $\frac{(\%\ \text{Total Solids} - \%\ \text{Soluble Solids})}{\%\ \text{Total Solids}} \cdot 100$

[2] For each harvest, within a given column, values having a letter in common do not differ significantly ($p = 0.05$).

If no letters are given the effects of storage were not significant.

of harvest and storage time. The losses were not excessive in any of the harvest lots when they were washed promptly i.e. within 4 hr of harvesting. As the time of storage increased, the losses became excessive in the lots harvested at the customary time, when the tomatoes were in somewhat riper condition.

Important relationships were also found to exist between the percentages of tomatoes with visible locules, determined either before or after washing, and the percent loss in weight through washing. The data are presented in Fig. 3 and 4. The relationship of the percentage of tomatoes with visible locules to the percent loss by weight proved to be very significant ($p < 0.001$).

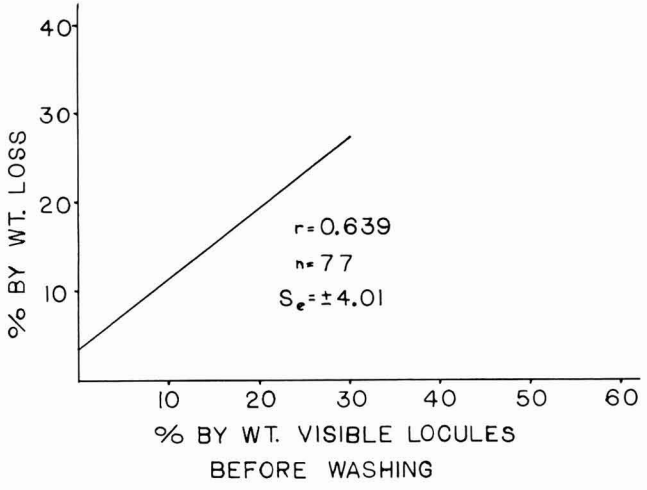

FIG. 3. RELATIONSHIP OF PERCENT BY WEIGHT VISIBLE LOCULES DETERMINED BEFORE WASHING TO PERCENT BY WEIGHT LOSSES THROUGH COMMERCIAL WASHING OF TOMATOES

Visible locules before washing were determined on core samples taken from each test load. The line is defined as % by weight loss = 0.789 · (% vis. loc. *before* washing) + 3.61.

These data also indicate that as the percentage by weight of tomatoes with visible locules increased, the percentage by weight of tomatoes in the undamaged category decreased and the percentage by weight of tomatoes in the major damage category increased by a disproportionate amount. A 1.4 percent decrease in undamaged tomatoes corresponded to a 0.9 percent increase in tomatoes with major damage for each

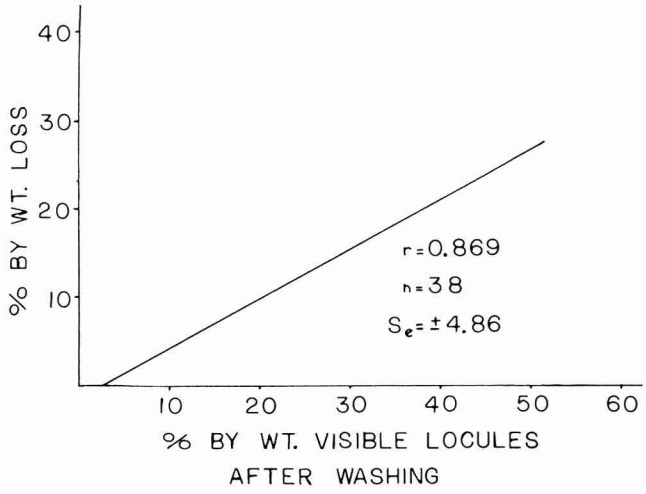

FIG. 4. RELATIONSHIP OF PERCENT BY WEIGHT VISIBLE LOCULES DETERMINED AFTER WASHING EACH LOAD (1½–2 TONS EA) TO THE PERCENT BY WEIGHT LOSSES MEASURED THROUGH COMMERCIAL WASHING OF THE TOMATOES

The line is defined as % by weight loss = 0.558 · (% vis. loc. *after* washing) — 1.24.

percentage increase in visible locules. Since crushed and bruised tomatoes along with visible locules make up the major damage category, it is these types which probably account for the disproportioned weight losses recorded. Fruits classified as crushed probably become visible locules while those classified as bruised account for a part of the loss in weight that was found to occur during washing. These findings resulted from washing 38 lots weighing 1½–2 tons each. Correlation coefficients relating the percentage by weight of visible locules to the percentage by weight of undamaged fruit remaining, or to the percentage by weight of tomatoes with major damage found after washing were —0.93 and 0.90, respectively.

Visible locules are a form of damage which can be easily recognized. They make a useful index of tomato condition because several important measures of tomato condition are proportionately influenced by the factors which produce visible locules. Ries and Stout (1962) found that counting cracked tomatoes after the washing process was completed was the preferable method for measuring harvest damage. This study also indicates that determining the percentage of visible locules after washing is the best method of determining tomato condition for

processing. However, when the significance of damage must be quickly estimated or the condition which caused it studied for corrective purposes, subsampling before washing to determine the percentages of visible locules is the preferable procedure. The relationships of percent visible locules in the subsamples to the other factors of tomato condition after washing can be expected to vary with the severity of the wash in the various commercial units used, but they should remain meaningful for specifying tomato condition before processing.

CONCLUSIONS

The data reported apply specifically to the VF145-7879 variety tomatoes grown in Yolo County, CA, harvested at a rate of 3–4 acres per working day, and handled in 1/2 ton bulk units. The data indicate that the stage of maturity at harvest had a profound influence on the ability of the tomatoes to withstand commercial machine harvesting, bulk handling and storage. Tomatoes harvested at regular field maturity were significantly more susceptible to damage from both transportation and storage than were the loads which were harvested 12 and 7 days earlier. Loads harvested 12 days before the regular harvests began did not show any significant changes in condition caused by either transportation or storage. The data on the 24 and 48 in. bins indicated that increasing the tomato depth would increase damage, thus reduce both the peelable and undamaged units in a load. Visible locules appeared to be a reliable index of tomato condition.

All the data indicate that if damage and direct losses in bulk bin loads are to be reduced, early harvesting, controlling fill depth, and reducing storage time need to be considered. The work needs to be expanded to cover fast harvest rates, bulk truck deliveries, and should be repeated on varieties being considered as replacement for the VF145 strain used in this study.

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AIR CLASSIFICATION OF BEAN FLOUR

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ABSTRACT

California small white beans were ground in a hammer-mill followed by milling in a turbo-mill and then air classified at 25 m^3/hr air velocity. This yielded a fine fraction containing about 44% protein and a coarse fraction containing most of the bean starch. The hulls being dense were collected with the coarse fraction resulting in a low fiber protein concentrate in the fine fraction. The fine fraction, in addition to having double the protein concentration of the starting material, also has double the concentration of fat, P, S, and K and one and a half times the concentration of sugars and ash but only a third of the fiber concentration.

INTRODUCTION

Beans are a very good source of protein and when supplemented with methionine their nutritional quality is similar to that of casein (Kon *et al.* 1971). Because of their relatively high content of lysine, beans may be used in combination with cereal or other products to increase the nutritional qualities of many of those products. A combination of beans and sesame seeds, in the right proportions, is particularly nutritious and can replace milk and milk products in weaning foods for infants in countries where milk is in short supply. When beans are to be used for this purpose it will be beneficial to have a preparation of beans which is higher in protein content than the whole bean.

This report describes preliminary results of air classification of bean flour for the purpose of obtaining a fraction high in protein, together with some evaluation of the two fractions obtained from such classification.

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MATERIALS AND METHODS

California small white beans grown in the Salinas Valley of California were obtained from the growing area. The milling was done first on a hammer-mill (Jacobson Machine Works, Inc. Minneapolis, Minn.) equipped with 0.063 screen, followed by a passage through Hurricane turbo grinder made by Pillsbury Mills, Inc. Minneapolis, Minn. The air classifier used was a laboratory size made by Walter-Stanbtechnik GMBH Köln-Dellbruck with variable air flow of 1 to 30 m^3/hr. Some gelatinization properties were determined with a Visco-amylo-graph made by Brabender Instruments, Inc. South Hackensack, N.J. and with a Bostwick consistometer (Davis *et al.* 1954).

For the experiments using the amylograph 50 g material in 450 ml distilled water was used. The slurry was stirred for 5 min at 30°C and then heated for about 45 min at a rate of 1.5°C/min to a maximum of 97°C. The material was held at that temperature for as long as required for maximum viscosity development. The amylograph was equipped with a 700 cmg sensitivity cartridge.

When the Bostwick was used, 15 g flour was suspended in 150 ml distilled water, cooked on a steam bath for about 20 min and maintained stirring at 60°C. The slurry was put in the Bostwick and the distance traveled in 10 sec, after opening the gate, was recorded (high distance indicates low viscosity).

RESULTS AND DISCUSSION

As can be seen from Tables 1 and 2, air classification can indeed be used to obtain a fraction enriched with protein from beans, similar to results obtained for wheat (Stringfellow *et al.* 1962). The concentration of protein in the fine fraction is double the concentration in the original turbo-milled material. In order to get any kind of a distribution between the fine and coarse fractions the material put through the air classifier had to be turbo-milled first. Regrinding the ground material on the hammer-mill equipped with a 0.026 screen did not help at all and only a fraction of a percent could be recovered as the fine fraction at maximum air velocity. As can be seen from Table 1, air velocity makes a big difference in the distribution of material between the two fractions, however, it is quite clear that there is no significant difference in the concentration of protein in the fine fractions obtained with different air velocities. Due to the fact that the best distribution was obtained at the highest air velocity setting, we used this air velocity (25 m^3/hr) for the production of material used in these experiments.

Table 1. Dry weight composition of fractions obtained from air classification with different air velocities

Materials	% of Totals	Protein (N X 6.25) %	Fat %	Fiber %	Ash %	Sugar %	P %	S %	K %	Ca %
Hammer milled		21.38	1.87	6.41	4.06	6.78	0.45	0.23	1.71	0.05
Turbo milled		21.73	1.94	5.23	3.98	6.74	0.46	0.25	1.61	0.07
Air classified:										
Fine fractions										
15 m^3/hr	6	43.26	3.87	2.65	7.08	10.19	0.87	0.41	3.25	a
20	16	45.68	3.90	1.63	7.36	10.38	0.95	0.44	3.49	a
25	20	43.59	3.49	1.69	6.51	9.96	0.84	0.41	3.02	a
Coarse fractions										
15 m^3/hr	94	17.30	1.58	6.12	3.48	6.21	0.32	0.18	1.34	0.07
20	84	16.42	1.62	5.29	3.16	5.67	0.28	0.15	1.23	0.05
25	80	15.28	1.36	5.38	3.04	5.35	0.27	0.15	1.14	0.09

[a]Below detection limit

Table 2. Viscosity development as measured by the visco-amylograph

Materials	Temp. at Which Thickening Starts	Viscosity at End of Heating Cycle	Peak Viscosity	Time Held for Max. Vis. Min
Hammer milled	69	180	230	21
Turbo milled	62	180	290	15
Air classified:				
Coarse fraction	69	300	380	12
Fine fraction	56	140	—	—

As can be seen in Fig. 1, the heavier starch granules remain in the coarse fraction while the lighter protein material is carried to the fine fraction. It is quite clear that some starch granules, especially the smaller ones, are being carried to the fine fraction together with the protein material. Polarized light was used in order to detect starch granules which are birefringent with a characteristic cross pattern under those conditions.

A close examination of Fig. 1, and other microscopic preparations, reveals that most of the seed coat material is present in the coarse fraction. This observation is confirmed also by the results of the chemical analysis of the two fractions shown in Table 1. The fiber content of the fine fraction is only 30% of its content in the turbo-milled material. Because of the fact that the hulls are concentrated in the coarse fraction during air classification there is no need to use dehulled beans when using this method to obtain an enriched protein fraction.

The fact that the fine fraction contains very little starch is verified by the results shown in Table 2. The viscosity development in the visco-amylo-graph depends on the gelatinization of the starchy material. The more starchy material the more viscous the material becomes and the higher the reading on the amylograph. As can be seen from Table 2, the fine fraction has the lowest reading at the end of the heating cycle; at this point the run had to be stopped as the material boiled out due to better heat transfer and lower surface tension. The fact that the fine fraction does not develop increased viscosity with heating does not mean that this fraction is not viscous. As a matter of fact, this fraction is much more viscous than either the turbo-milled material or the coarse fraction. The drainage time of a 10% solution at room temperature of each of the three out of a 1 ml pipet is 5 sec for turbo-milled material, 3 sec for coarse fraction, and 20 sec for fine fraction. This is in

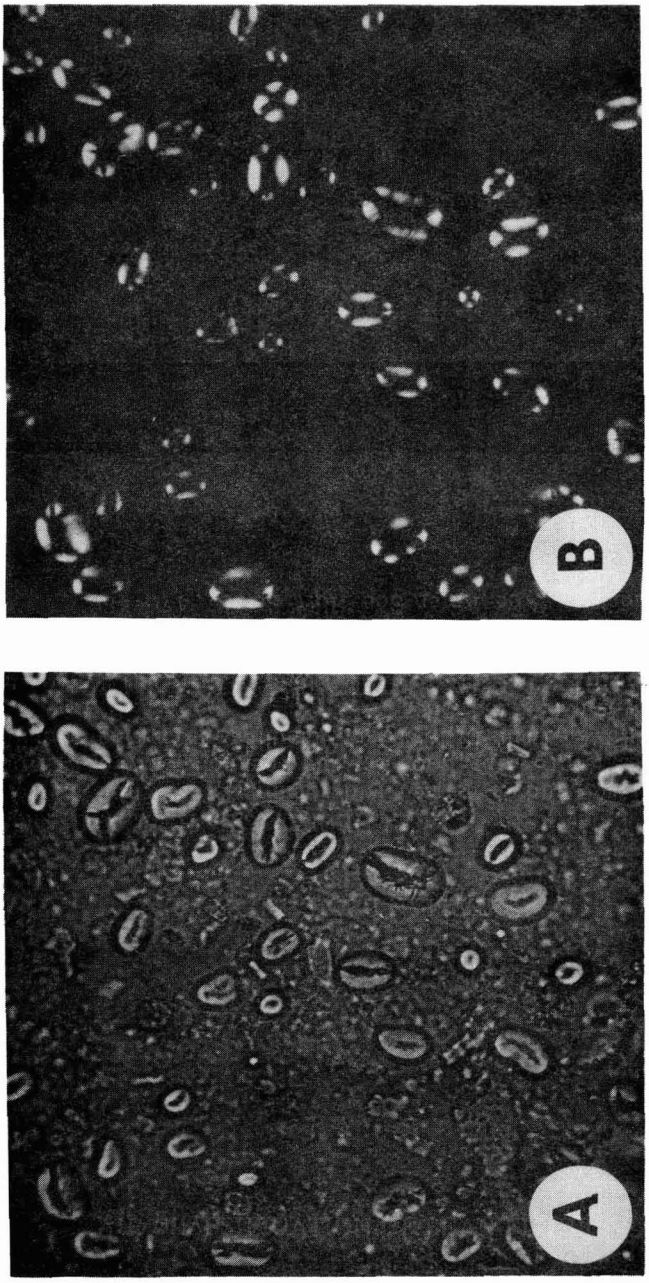

FIG. 1. PHOTOMICROGRAPH OF WATER SUSPENSION OF BEAN FLOURS USED
a. Turbo-milled flour; b. the same under polarized light.

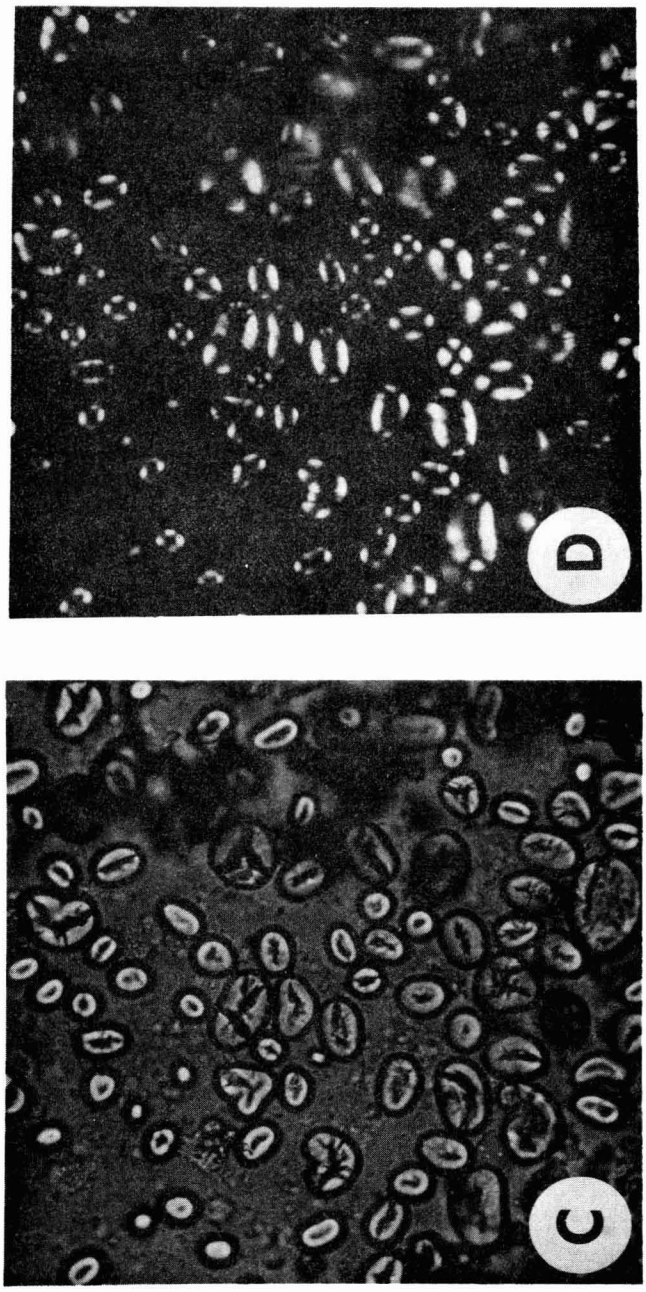

FIG. 1. PHOTOMICROGRAPH OF WATER SUSPENSION OF BEAN FLOURS USED
c. Coarse fraction flour; d. the same under polarized light.

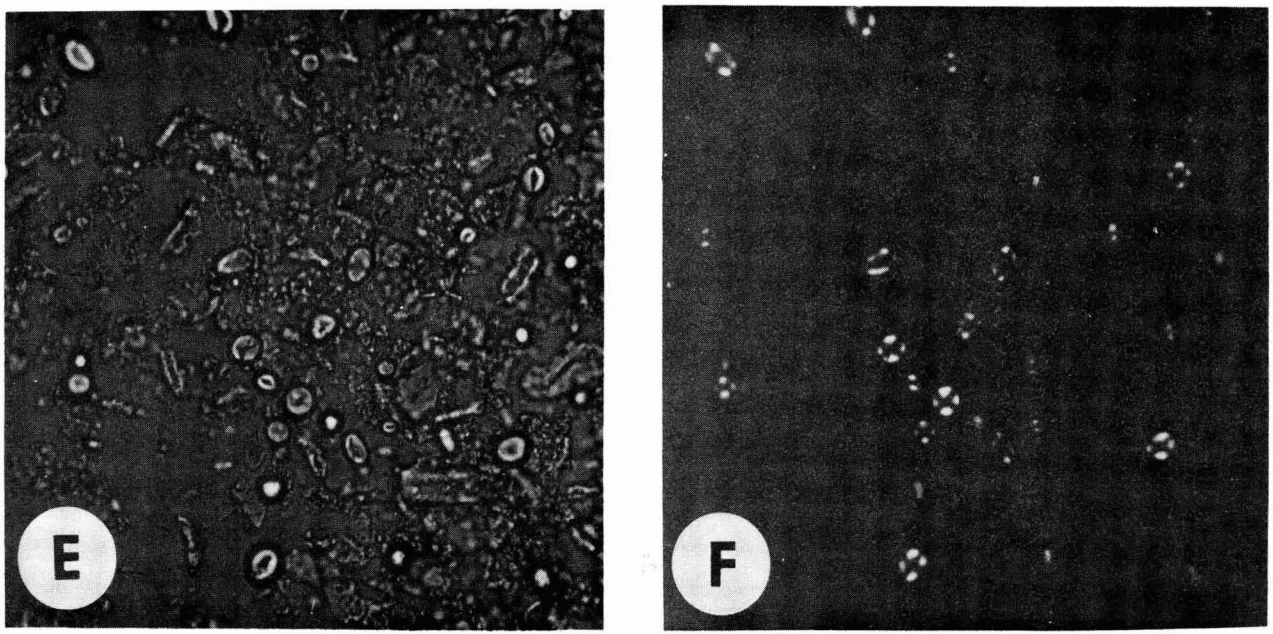

FIG. 1. PHOTOMICROGRAPH OF WATER SUSPENSION OF BEAN FLOURS USED

e. Fine fraction flour; f. the same under polarized light.

agreement with previous observations by us and with the results reported by Circle *et al.* (1964) that legume protein form quite viscous solutions.

The combined effect of starch gelatinization and protein viscosity was observed by measuring the consistency of the material with a Bostwick consistometer. The results obtained were: 6.5 cm for turbo-milled material, 6.0 cm for the fine fraction, and 1.5 cm for the coarse fraction. The reason that the results here are presumably inconsistent with the results obtained with the visco-amylo-graph, is that on the visco-amylo-graph, the results show viscosity development when the temperature rises from 30° to 97°C while on the Bostwick the results show the viscosity of each of those samples at 60°C.

As can be seen in Table 1 the oil moiety was also enriched in the fine fraction together with P, S, and K; the concentration of each doubled compared to its concentration in the turbo-milled material. This is the same enrichment observed for protein. Sugar and ash, while being enriched in the fine fraction, their concentration is only about 1½ times greater than in the turbo-milled material. The enrichment of sugars includes 1½ times enrichment of all the bean sugars including sucrose, raffinose, and stachyose. This was verified by gas liquid chromatography of their trimethylsilyl derivatives as described by Becker *et al.* (1974). The finding that sugars are being concentrated in the protein fraction is in agreement with the results reported for wheat flour by MacArthur and D'Appolonia (1976). The fine fraction has only about 30% the concentration of fiber, and Ca, if present at all, is below detection limit. The results found for Ca and P are in agreement with the results reported by Chang (1975) and Lolas and Markakis (1975) that most of bean phytic acid is water soluble. It seems that most of the Ca in beans is associated with bean fiber, which is in agreement with results reported by Kon (1968).

This report shows that air classification can be used to obtain a fraction of bean flour high in protein; unfortunately this fraction is also enriched with sugars. Some of the bean sugars especially the galacto-oligosaccharides raffinose and stachyose have been implicated as contributing to flatulence (Cristofaro *et al.* 1970; Becker *et al.* 1974; Wagner *et al.* 1977) so that the use of this fraction in protein enrichment, and as a milk substitute might be limited.

Reference to a company and/or product named by the Department is only for purposes of information and does not imply approval or recommendation of the product to the exclusion of others which may also be suitable.

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CONSEQUENCES OF DAMAGE ON THE UTILIZATION CHARACTERISTICS, YIELD, AND QUALITY OF PROCESSED TOMATOES

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ABSTRACT

*Tomatoes of VF*145-7879 *variety were commercially machine-harvested at three levels of ripeness. The effects of commercial handling in* 1/2*-ton-bin units were measured in terms of damage and loss by weight. Tomato lots differing in damage and weight loss were made into concentrates which were remanufactured into standardized catsup. As the amount of tomatoes with visible locules and major damage increased, weight losses were higher, recovery of tomatoes suitable for peeling was lower, and less catsup was produced per ton of harvested tomatoes. Peeling losses increased from* 15.1% *on undamaged tomatoes to* 50.7% *on tomatoes with exposed seed locules. Damage influenced the final pH and acidity of the canned peeled tomatoes, and significantly related to changes in the solids, serum viscosity, microbiological quality, and yield of standardized catsup produced from the respective loads of tomatoes.*

INTRODUCTION

In hand-harvest days, some damage to tomatoes was considered inherent and unavoidable. When industry changed to once-over mechanical harvesting and bulk handling of tomatoes, the damage in commercial loads of tomatoes grew into a serious problem (O'Brien *et al.* 1963; O'Brien 1972; Calif. Tomato Growers 1976). Ries and Stout (1962), Ries *et al.* (1961), and O'Brien (1972) *et al.* (1963, 1965) extensively studied damage and the mechanism of damage. Denny and Bohrer (1964), York *et al.* (1964, 1967), and NCA (1966) investigated the

[1] Deceased

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microbiology of tomatoes as affected by machine harvest. Leonard *et al.* (1977) evaluated direct losses in bin loads harvested at different levels of ripening, relating tomato condition to storage and ripeness level at harvest, and showing that the percent by weight of tomatoes with visible locules predicted the condition of tomatoes for processing and direct weight losses through washing.

The present study relates tomato condition to yield, utilization characteristics, and the quality of two dominant tomato commodities in the U.S. (Judge and Sons 1976a), whole peeled tomatoes and tomato concentrates remanufactured into tomato catsup.

EXPERIMENTAL

Harvesting

Tomatoes of VF145 variety were commercially machine-harvested at 3 stages of ripeness into plastic-lined 48 × 48 × 24 in. bins at the rate of 3–4 acres per day. Harvesting was scheduled with growers to secure a minimum of three replicate loads 12 days and 7 days earlier than, and also at the same time that a grower would harvest his fields for the processor, based on the percent deliverable to percent grass green tomato ratio (Leonard *et al.* 1977).

Sampling

Tomatoes were weighed on arrival at the laboratory, after which bins were core-sampled from top to bottom by hand to eliminate the damage inherent in mechanical sampling. The core samples were weighed (about 50 lb) and used to obtain analytical information on raw-material condition on receipt and at various times of processing (after storage for 4, 24, or 48 hr which covers the range of time lag observed in industry).

Washing and Sorting

The tomatoes were alternately soak- and spray-washed twice at the rate of approximately 450 gallons of chlorinated water per ton of tomatoes. The washed tomatoes were sorted into categories as to their suitability for peeling or crushing and the incidence of mechanical damage and natural defects such as mold, sunburn, etc. (Leonard *et al.* 1977). All tomatoes were weighed on arrival, before and after washing. Percentages of weight loss, and percentages of tomatoes with visible locules or major damage were calculated on the basis of harvested

weight. Percentages of tomatoes which were crushed or bruised or had exposed seed locules (visible locules) were grouped for analysis as major damage.

Peeled Tomatoes

Sample lots of tomatoes were lye-peeled at 103.3°C in an FMC continuous lye peeler (FMC Corp., San Jose, CA.) operated at 44 flights per minute (about 1 min residence) with 14% NaOH solution. Peeling losses were calculated from the weight difference between unpeeled and peeled tomatoes. Peeled samples for analysis were filled into 401 × 411 cans and processed 32 min at 100°C in a rotary atmospheric cooker.

Preparation of Concentrates

Tomatoes for concentrate were processed through a steam-injection hot-break system averaging 9 lb tomatoes per min, initial temperature 107.2°C, 35-sec hold, and 101.7°C at the end of holding. Seeds and skins were removed in a Brown Citrus Extractor fitted with 0.027-in. screen, operated under 10 lb pressure. The extracted pulp was immediately cooled to <38°C and concentrated in a wiped-film evaporator (WFE, Pfaudler Co., Sybron Corp., Rochester, N.Y.) to about 15, 20, and 25% total tomato solids.

Chemical, Physical, and Microbiological Analyses

Total solids, soluble solids, pH, and titratable acidity were determined by methods of AOAC (1970). Solids and acidity are given in percentages by weight. Percent dry weight insoluble solids were calculated, prior to statistical analysis, as follows:

$$\% \text{ dry wt. insoluble solids} = \frac{\% \text{ total solids} - \% \text{ soluble solids}}{\% \text{ total solids}} \times 100$$

To determine serum viscosity, pectic enzymes in the tomatoes were inactivated by heating in a microwave oven (2 magnetrons, 800 watts ea.). After cooling and adjusting for vapor losses, seeds and skins were removed through a laboratory-size pulper, the pulp was centrifuged, and the serum viscosity of the filtered serum was measured at 30°C (Leonard *et al.* 1977). Serum viscosity is reported in centistokes, where cs = flow time (sec) × k (calibration constant of viscometer).

Since tomato concentrates are only an ingredient for the preparation of solids and/or consistency-dependent tomato foods, their remanufacturing characteristics were measured in terms of consistency.

A concentrate representing each lot was converted to a catsup that contained 33% of total solids (32% natural tomato soluble solids), with a Bostwick value of 6 cm by a laboratory procedure developed by Marsh *et al.* (1977). The method determines the percentage of tomato solids required by the catsup formulation to reach the fixed values of the standard laboratory batch. The amount of tomato solids required to make 100 lbs of catsup, which can be determined by using this percentage value, becomes a useful function for comparative purposes.

Serum mobility, which indicates the amount of soluble polymers (pectic materials) in the catsup, was determined by measuring the horizontal distance the serum migrated through blotter paper when 5 ml of catsup was spread evenly over a circle 4 cm in diameter. The area wetted by the catsup, not including the area of the circle where the sample was applied, was related to original serum viscosity.

Total bacterial counts were made on tomatoes representing the washed and sorted load. The tomatoes were macerated and pour-plated in GTY agar (glucose-tryptone-yeast extract). Colonies were counted after 48 hr at 30°C. Mold counts, made on 9% total solids dilutions of concentrates, represent the number of positive fields in 100 examined.

RESULTS AND DISCUSSION

The first consequence of tomato condition is the loss in weight measured from harvest through washing (Table 1). The minimum average weight loss was 1.5% in loads harvested 12 days early and processed within 4 hr of harvest. As harvest was delayed and post-harvest storage times were increased, the weight loss increased to an average of 28.9%. Translated into industry-wide losses in dollars, these percentages amount to millions. Such losses, related to quality attributes, also markedly increase the cost of waste disposal (Calif. Tomato Growers Assoc. Inc., 1976).

Statistical analysis of tomato weight losses from harvest through washing indicate a series of significant ($p < 0.05$) relationships as shown in Table 2.

These relations show, for example, that as weight losses increased, the yield of catsup per ton of tomatoes harvested decreased. The decrease in serum viscosity and increase in mold and bacteria are believed to have resulted from the factors which caused the losses, not directly from the losses themselves.

The negative correlation between weight loss and pounds of tomato solids required to produce 100 pounds of catsup appears to be inconsistent with the catsup yield per ton. This discrepancy can be explained

Table 1. Influence of early harvest and storage time on weight losses, damage, microbiological condition and the yield of 6 Bostwick fancy catsup (33% total solids)

Storage Period and Harvest Time	Weight Loss Through Washing (%)	Visible Locules (%)	Major Damage (%)	Total Bacteria no./g Tomatoes	Lb Tomato Solids Required/100 lb Standardized Catsup	Lb Catsup per Ton of Harvested Tomatoes
Tomatoes processed within 4 hr of harvest (average ± one standard deviation)[a]						
12 days early	1.5 ± 1.0	2.3 ± 0.3a	8.9 ± 2.1a	9.47×10^3	12.8 ± 0.2	866 ± 35
7 days early	2.4 ± 1.3	5.2 ± 2.8a	20.1 ± 2.6b	—	14.6 ± 2.0	781 ± 97
Regular	3.6 ± 3.3	15.1 ± 6.3b	29.5 ± 7.8c	1.37×10^4	14.1 ± 1.5	794 ± 24
Tomatoes processed after 24-hr storage						
12 days early	4.1 ± 1.0	4.8 ± 2.5a	15.0 ± 4.1a	2.30×10^4a	12.6 ± 0.6	807 ± 14
7 days early	3.9 ± 0.4	7.9 ± 2.4a	34.5 ± 3.6b	—	15.5 ± 1.6	745 ± 57
Regular	6.9 ± 2.5	26.6 ± 7.6b	41.3 ± 10.1b	7.55×10^5b	15.1 ± 1.2	704 ± 36
Tomatoes processed after 48-hr storage						
12 days early	2.2 ± 1.1a	4.2 ± 0.2a	17.8 ± 0.2a	1.10×10^5a	12.9 ± 0.8	850 ± 47a
7 days early	7.4 ± 1.6a	11.6 ± 3.4b	40.8 ± 5.9b	—	14.4 ± 0.3	789 ± 5a
Regular	28.9 ± 8.0b	45.8 ± 4.2c	61.9 ± 4.5c	2.10×10^6b	14.9 ± 1.2	566 ± 60b

[a]Values in each column without letters or with a letter in common do not differ significantly ($p < 0.05$). The letter a indicates the best condition, and c the worst.

Table 2. Various aspects of tomato quality as related to weight losses between harvest through washing

Variable	Correlation Coefficient[b]	Slope of the Line of Regression
Percent change[a]		
In serum viscosity	−0.69	−1.11
In % dry-weight insoluble solids	0.41	0.88
Log_{10} no. bacteria per g tomatoes	0.67	0.06
Mold counts (% positive fields)	0.87	2.20
Lb tomato solids required per 100 lb fancy catsup	−0.58	−0.08
Lb fancy catsup per ton of tomatoes harvested	−0.76	−9.71

[a]Indicates percentage change between receiving and time of processing
[b]All correlations are significant at $p < 0.05$

by data in Table 5 and damage data in Table 1.

There is a loss in soluble solids during storage for 24 hr and 48 hr between receiving and processing. Visible locules facilitate both direct loss of locular material (soluble solids) and the washing of locular material from the locule. Such losses, principally soluble solids, increase the percent by weight of water insoluble solids. Since consistency partially depends on insoluble solids (York *et al.* 1967), the consistency-oriented catsup would appear to require less pounds of tomato concentrate as soluble solids are lost. The direct losses, however, were not compensated for by the improvement in consistency associated with the loss in soluble solids. For each percent increase in weight loss, an average of 9.7 lb less catsup was produced per ton of harvested tomatoes.

Increased weight losses are a direct consequence of tomato damage incurred in mechanical harvest and bulk handling and storage. The percentage of tomatoes with visible locules determined after washing has been shown to indicate the quality of tomatoes for processing (Leonard *et al.* 1977). This index was found to relate to factors of quality and yield as well. The relationships are shown in Table 3. All correlations are significant ($p < 0.05$).

The significance of these correlations, however, does not necessarily imply a cause-and-effect relation between the two variables; it may indicate that both are affected by circumstances to which the tomatoes were subjected. For example, changes in both composition and microbiological condition depend on progressive breakdown of the fruit's

Table 3. Various aspects of tomato quality as related to percent tomatoes with visible locules

Variable	Correlation Coefficient[b]	Slope of the Line of Regression
Percent changes[a]		
In serum viscosity	−0.56	−0.58
In soluble solids	−0.42	−0.11
In % dry weight insoluble solids	0.42	0.58
Log_{10} no. bacteria per g tomatoes	0.75	0.06
Mold counts (% positive fields)	0.78	1.00
Lb tomato solids required per 100 lb fancy catsup	−0.48	−0.04
Lb fancy catsup per ton of tomatoes harvested	−0.75	−5.84

[a]Indicates percentage change between times of receiving and processing
[b]All correlations are significant at $p < 0.05$

physical structure from harvest to processing. Time is a factor not only in increasing the amount of tomatoes with visible locules and major damage but also in microbial growth and the enzymatic degradation of pectic materials, as reflected in the number of bacteria or mold counts, and in serum viscosity. The relationships of the listed variables to the percent tomatoes with visible locules resemble those for the weight losses. The percent soluble solids, however, had no significant relationship to weight losses, but did relate significantly both to the percentage of tomatos with visible locules and to major damage.

Table 4 shows the relationships of quality and yield to percent washed tomatoes with major damage. All correlations listed are statistically significant ($p < 0.05$). The relationships are all similar to those found for weight losses and tomatoes with visible locules. Thus, serum viscosity, soluble solids, pounds of tomato solids required, and catsup yield decrease with higher percentages of major damage, whereas the number of bacteria, mold counts, and insoluble solids increase.

The consequences of tomato damage are not very clear in terms of changes in composition, as Table 5 indicates. In paired analyses, the changes in composition from receiving to processing were not significant for tomatoes processed within 4 hours. With storage for 24 or 48 hr before processing, however, the percentage of total and soluble solids dropped significantly, ($p < 0.01$), resulting in the indicated percentages of dry weight insoluble solids. Only with 48 hr of storage did decreases in serum viscosity become significant ($p < 0.01$).

Table 4. Various aspects of tomato quality as related to percent tomatoes with major damage

Variable	Correlation Coefficient[b]	Slope of the Line of Regression
Percent change[a]		
In serum viscosity	−0.61	−0.60
In soluble solids	−0.57	−0.14
In % dry weight insoluble solids	0.45	0.57
Log_{10} no. of bacteria per g tomatoes	0.70	0.05
Mold count (% positive fields)	0.60	0.57
Lb tomato solids required per 100 lb fancy catsup	−0.41	−0.03
Lb fancy catsup per ton of tomatoes harvested	−0.72	−4.92

[a]Indicates percentage change between receiving and processing
[b]All correlations are significant at $p < 0.05$

Even though fruit composition changed more subtly than did fruit physical condition, composition affected final yield and quality. Table 1 shows yield figures calculated for a ton of harvested tomatoes. When the weight losses averaged 1.5% and tomatoes with visible locules or major damage were not excessive, total tomato solids at processing were 5.62% (Table 5) and the final yield of 6 Bostwick fancy catsup (33% solids) was 866 lb. When increased damage caused an average weight loss of 28.9%, the tomatoes had more solids (5.92%, Table 5) but the catsup yield decreased 35% (to 566 lb). The quality of the catsup was also affected by the reduction in serum viscosity of the tomatoes. The amounts of soluble polymers (mostly pectins), estimated from tomato serum viscosity, affect the appearance (sheen) of the catsup and its ability to bind the liquid components. When retention of the pectic materials was poor, the resulting catsup tended to bleed; there was a separation of the liquid components. This tendency to separate, determined with the blotter test, significantly correlated ($p < 0.001$) with retention of the original serum viscosity from the raw material. The correlation coefficient was −0.84, and the results implied that with lower retention of the inherent serum viscosity, serum in the resulting catsup or product will separate more easily and rapidly.

In terms of color quality, all experimental sample loads passed the canning tomato inspection requirements for acceptability for processing. Statistical analysis of the color data indicated that the color of

Table 5. Consequence of damage: Changes in the composition of raw tomatoes from receiving through washing; Tomatoes were received within 1 hr of harvest; Data are average values ± one standard deviation

Storage Period and Harvest Time	% Total Solids at Time of:		% Soluble Solids at Time of:		Serum Viscosity (cs) at Time of:		% Dry Weight Insoluble Solids at Time of:	
	Receiving	Processing	Receiving	Processing	Receiving	Processing	Receiving	Processing
Tomatoes processed within 4 hr of harvest								
12 days early	5.42 ± 0.05	5.62 ± 0.10	4.78 ± 0.06	4.93 ± 0.01	3.78 ± 0.37	3.46 ± 0.06	11.73 ± 0.24	12.58 ± 1.34
7 days early	5.79 ± 0.53	5.69 ± 0.42	5.09 ± 0.46	5.09 ± 0.42	3.57 ± 0.44	3.50 ± 0.56	12.03 ± 2.17	11.75 ± 1.69
Regular	5.59 ± 0.65	5.58 ± 0.57	4.94 ± 0.78	5.00 ± 0.61	3.13 ± 0.32	2.98 ± 0.54	11.94 ± 3.79	10.56 ± 1.72
Tomatoes processed after 24-hr storage								
12 days early	5.38 ± 0.21	5.30 ± 0.23	4.75 ± 0.20	4.66 ± 0.25	3.71 ± 0.38	3.54 ± 0.66	11.71 ± 0.20	13.13 ± 0.44
7 days early	6.22 ± 0.27	5.48 ± 0.37	5.64 ± 0.26	5.26 ± 0.26	3.78 ± 0.41	3.60 ± 0.34	9.25 ± 1.39	11.26 ± 1.04
Regular	5.95 ± 0.51	5.74 ± 0.61	5.32 ± 0.51	5.05 ± 0.54	3.25 ± 0.75	2.90 ± 0.66	10.65 ± 1.10	12.08 ± 1.01
Tomatoes processed after 48-hr storage								
12 days early	5.73 ± 0.29	5.62 ± 0.01	5.08 ± 0.32	4.95 ± 0.08	3.92 ± 0.15	3.43 ± 0.27	11.38 ± 1.07	11.92 ± 1.29
7 days early	6.23 ± 0.15	5.97 ± 0.01	5.56 ± 0.16	5.43 ± 0.20	3.94 ± 0.29	3.39 ± 0.61	10.39 ± 1.05	12.10 ± 0.30
Regular	5.97 ± 0.52	5.92 ± 0.44	5.38 ± 0.51	5.07 ± 0.45	3.37 ± 0.54	2.12 ± 0.25	10.04 ± 0.80	14.47 ± 1.37

tomatoes did not change significantly as a result of either damage or storage.

Evaluation of changes in nutritional value of the tomatoes was not considered at this time. However, Krochta *et al.* (1975) showed that in severely damaged tomatoes (equivalent to tomatoes with visible locules), the ascorbic acid content dropped 15%. Additional work on changes in nutritional and flavor quality as related to tomato condition, may be desirable.

The consequence of tomato condition on utilization characteristics was measured also in terms of peeling or processing as a crushed product. The recovery of units which can be peeled is influenced by harvesting, handling, and washing but depends primarily on field conditions during growing. Still, the number of peelable units in loads harvested from the same field decreased significantly ($p < 0.001$) as damage increased in those loads.

The influence of lye peeling was measured on tomatoes classed as undamaged, on tomatoes with >1-in. cracks in the skin, and on tomatoes with visible seed locules. The results are in Table 6. Peeling losses and pH were significantly greater for the severely damaged tomatoes. The condition of loads destined for peeling thus needs special consideration. Losses in crushing for concentrate products involve weight losses through washing, and the extraction of seeds and skins which can be standardized at 2½–3½% by weight. Losses in lye peeling also include losses through washing but, instead of a small constant loss of extracted seeds and skins there are larger peeling losses which depend primarily on fruit condition. For example, peeling losses may increase from 15.1% for undamaged tomatoes to 50.7% for tomatoes with exposed seed locules or similar serious damage. A load of tomatoes may appear suitable for peeling on the top layers, but damage increases toward the bottom in bulk loads making it difficult to estimate the amount of damage that will be encountered (O'Brien 1974). To prevent extensive losses, loads should either be screened for damage by subsampling before washing or should be sorted for damage before entering the lye peeler.

Tomato materials, whether lost through washing or peeling, are considered wastes which are either recovered or disposed of, requiring significant expenditures (Calif. Tomato Growers Assoc. Inc. 1976). The worse the condition of a load of tomatoes, the higher will be the costs for usable product. That is, increased direct losses result not only in less food produced per dollar of raw material purchased, but also in increased cost of disposal of the larger amount of tomato material lost.

Table 6. Influence of tomato condition on peeling losses and the acidity of canned whole peeled tomatoes

Tomato Condition	Peeling Loss % by Wt	pH	Citric Acid % by Wt	Retention[a] % by Wt
Undamaged tomatoes	15.1 ± 7.6a[b]	4.27 ± 0.11a	0.335 ± 0.019a	92.7 ± 2.1
Tomatoes with >1-in. cracks in the skin	20.1 ± 5.7a	4.30 ± 0.10a	0.307 ± 0.013b	92.0 ± 2.4
Tomatoes with visible locules	50.7 ± 6.6b	4.39 ± 0.10b	0.276 ± 0.019c	92.1 ± 2.1

[a]% retention = drained wt/fill wt
[b]Within a column, values having a letter in common do not differ at $p \leq 0.05$

CONCLUSIONS

The data show that damage affects the utilization potential, yield, and quality of processed tomatoes. Early harvest and minimal post-harvest storage time cause lower losses in yield and quality because with each the loads receive a lesser amount of damage. The difference in serum viscosity and dry-weight insoluble solids between loads harvested early or at the regular time was insignificant compared with the differences in physical conditions. While solids, acidity, and serum viscosity of the tomatoes showed no significant influence on the yield of processed tomato products, the factors of quality were affected by these constituents, which in turn appeared to be affected by the physical condition of the tomatoes.

The data indicate that it would be to a processor's advantage to harvest at an earlier date and process without delay to obtain better yields and higher retention of original quality. However the economic impact on the producer of harvesting at an earlier date needs to be evaluated.

ACKNOWLEDGMENTS

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BOOK REVIEWS

Principles of Food Science, Part I, Food Chemistry.[1] O. R. Fennema, Editor, Marcel Dekker, Inc., 270 Madison Ave., New York City 10016. 792 pp. 1976. $49.50.

As stated in the preface, this book is designed as a textbook for food science students with an organic and biochemistry background, and for those already working in the food industry. It can be said that this book fills that purpose and can be considered the best food chemistry text available. Even though the price is high, there is a special student discount (10%) and I would highly recommend it for senior/graduate level chemistry courses and a must for anyone who is conducting product development research. It is rare in that not only does it teach advanced food chemistry, but it also includes in-depth information on food formulation and its inherent problems. For example, the color chapter gives some clues at the end on how to improve the color of formulated foods by control of the particle size of lakes. Each initial section on food components also deals in depth with the functionality of the related ingredients.

The book is divided into seventeen chapters by various authors. The first eight deal with the major food components such as water, carbohydrates, lipids, etc. Current research findings are incorporated in the manner of *Advances in Food Science* which really makes the chapters worthwhile. For example, in the chapter on protein, lysinoalanine formation is discussed, which can be found nowhere else in a food chemistry text. The enzyme chapter brings in the new standardized nomenclature. The major criticisms of these chapters are their variability in depth and sometimes lack of depth. For example, a good enzyme kinetics example worked out in the text would have been useful. The same can be said for analytical methods although there are good texts in that area.

Chapter 9 on food flavors is not very good since it is mostly a sensory chapter and gives little information on the types of flavors in foods. It could be improved in future Editions. The next two chapters are excellent and deal with food additives and their function and toxic substances in foods. Finally, Chapter 12 discusses food dispersions with the good use of physical chemistry equations. It is too bad that working examples of the equations were not included.

[1] Reprinted with permission from *Food Technology*, Vol. 31, No. 3, pp. 123–124, 1977

The next four chapters deal with muscle, milk, eggs, and plant tissues. The chapters are excellent in integrating the food chemistry with the biochemistry but are quite repetitive in some places of earlier material. The book may have been cheaper if these were left out, but they significantly enhance the use of the text. The last chapter summarizes the book but in essence was not really needed since it is too short.

Any book always invites some criticism especially if it is multi-authored, which causes repetitions of basic information in many places. The editor did a marvelous job however, in having the various authors reference other sections of the book. If it is to be used as a text for a long time, it also needs a much more comprehensive index (only seventeen pages for 776 text pages; good engineering texts have double this). Again this is the problem of a multi-authored book. There however, are very few errors in the book and as the editor states in the preface, he invites reporting of them so that the book can be improved. I feel along with Volume II, Physical Principles of Food Preservation, also edited by Dr. Fennema, one could have a truly excellent compendium on basic food science and if used as texts in our departments, we could really train our students well. The two books would make an excellent gift to any food scientist.

THEODORE P. LABUZA

Principles of Food Science, Part II, Physical Principles of Food Preservation. O. R. Fennema, Editor, Marcel Dekker, Inc., 270 Madison Ave., New York City 10016. 474 pp. 1975. $39.50.

This book in Part II is a modern series on food preservation and food science principles. The book is authored by three people (Lund, Karel, and Fennema) so it is much more concise with few repetitions as in the Food Chemistry, Part I. This is an excellent textbook which could form the basis for an advanced senior or graduate level course.

The book is divided into five sections with a total of twelve chapters. After an introduction, the first section deals with heat and radiation preservation. The section on determination of lethality is excellent since it shows how really pure chemical kinetics can be used to determine the same thing as the classical methods. All chapters try to use both English and metric systems. The chapter on radiation of foods is interesting but probably of little value in this country unless the FDA

changes their ways. The second section deals with freezing and refrigeration and is an excellent reduction of Fennema's earlier book on low temperature preservation.

The next section deals with water removal and is excellent. It is the basis of a course taught by Dr. Karel at MIT and covers both concentration and drying. New research findings are incorporated into the text along with practical data. One fault could be the lack of problems and solutions so the student could follow a problem. The text deals with principles and keeps away from the strict empirical engineering-type solutions which really makes it excellent. The last chapter deals with packaging and again it is an excellent theoretical and practical development of predicting packaging requirements of foods.

One major fault as with Part I, is the short index (eight pages for 466 text pages). It would be helpful to extend this. Overall however, it is a book well-recommended for food science students and those in research in this area.

THEODORE P. LABUZA

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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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