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Edited by

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SEPTEMBER 1980

September 19—24: 13TH INTERNATIONAL TRADE FAIR OF THE FOOD INDUSTRY. Munich Fairgrounds, Munich, Germany. Contact Gerald G. Kallman Associates, 30 Journal Square, Jersey City, New Jersey 07306.

September 23—25: CONFERENCE OF SEA FOOD WASTE MANAGEMENT IN THE 1980's. Co-sponsored by the Coastal Plains Marine Center and Florida Sea Grant College. Orlando Marriott Inn, Orlando, Florida. Contact W. S. Otwell, Dept. of Food Science and Human Nutrition, University of Florida, Gainesville, FL 32611.

September 26: FOOD DEHYDRATION SYMPOSIUM. KANSAS STATE UNIVERSITY. Contact D. Y. C. Fung. Dept. of Animal Sciences and Industry. Kansas State University, Manhattan, Kansas 66506.

September 29—October 1: ASAE NATIONAL ENERGY SYMPOSIUM. Radisson Muehlebach Hotel, Kansas City, Missouri. Contact B. L. Clary, Agricultural Engineering Dept., Oklahoma State University, Stillwater, Oklahoma 74074.

September 30—October 2: ANNUAL CONFERENCE ON ENGINEERING IN MEDICINE AND BIOLOGY. Washington Hilton Hotel, Washington, D. C. Contact ACEMB, Suite 404, 4405 East-West Highway, Washington, D. C. 20014.

OCTOBER 1980

October 1: PLASTIC BOTTLE SEMINAR. Sponsored by Plastic Bottle Institute. Biltmore Hotel, New York City. Contact J. Malloy, Staff Director, Plastic Bottle Institute, 355 Lexington Avenue, New York, New York 10017.

October 5—8: IV BRAZILIAN CONVENTION OF FOOD SCIENCE AND TECHNOLOGY. Sponsored by SBCTA-Brazilian Society of Food Science and Technology, Rio de Janeiro, Brazil. Contact A. Borba de Olivera, Secretariat, Rua Jardim Botanico, 1024 Gavea, CEP, 22.460 Rio de Janeiro, RJ, Brazil.

October 6—8: INTERNATIONAL SYMPOSIUM ON ENERGY AND FOOD INDUSTRY. Madrid, Spain. Contact A. Bonastre, Secretary General, Commission International Des Industries, Agricoles et Alimentaries, 24, Rue de Teheran, 75008, Paris, France.

October 20—23: 35TH ANNUAL ISA CONFERENCE AND EXHIBIT. Houston, Texas. Contact C. T. Glazer, ISA, 400 Stanwix St., Pittsburgh, PA 15222.

October 21—24: NATIONAL FROZEN FOOD CONVENTION. MGM Grand Hotel, Las Vegas, Nevada. Contact K. E. Mulderig, National Frozen Food Association, Inc., Suite 100, 1700 Old Meadow Road, McLean, Virginia 22102.

October 26—31: INTERNATIONAL MEETING ON RADIATION PROCESSING. Miyako Hotel, Tokyo, Japan. Contact Y. Orita, Secretary General, Third International Meeting on Radiation Processing, P. O. Box 6, Kurango Takasaki, 37-12, Japan.

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November 3—6: UCD-FDA BETTER PROCESS CONTROL SCHOOL. University of California-Davis. Contact R. C. Pearl, Department of Food Science and Technology, University of California, Davis, CA 95616.

November 8—11: 75TH ANNUAL AMERICAN MEAT INSTITUTE CONVENTION. McCormick Place, Chicago, Illinois. Contact Dept. of Convention and Meetings, American Meat Institute, P. O. Box 3556, Washington, D. C. 20007.

November 9—14: WORLD CONFERENCE ON SOYA PROCESSING AND UTILIZATION. Acapulco, Mexico. Contact American Oil Chemists Society, 508 S. 6th St. Champaign, Illinois 61820.

November 10—13: FOOD TECH '80. Auckland, New Zealand. Contact Food Tech '80, Trade Publications, Ltd., P. O. Box 1614, Auckland, New Zealand.

November 16—19: 73RD ANNUAL MEETING OF AMERICAN INSTITUTE OF CHEMICAL ENGINEERS. Chicago, Illinois. Contact Edward Fochtman, Technical Program Chairman, 73rd AIChE Meeting, IIT Research Institute, 10 W. 35th St., Chicago, Illinois 60616.

November 24—28: COMBINATION PROCESSES IN FOOD IRRADIATION. Columbo Sri Lanka. Contact J. H. Kane, International Technical Conference Specialist, Office of Resource Applications, Department of Energy, Washington, D. C. 20545.

DECEMBER 1980

December 2—5: ASAE WINTER MEETING-ENGINEERING A SAFER FOOD MACHINE. Palmer House, Chicago, Illinois. Contact M. S. Purschwitz, ASAE Headquarters, Box 410, St. Joseph, MI 40985.

December 8—10: WORKSHOP ON ENERGY CONSERVATION AND FOOD PROCESSING. O'Hare Ramada Inn, Chicago, Illinois. Contact John J. O'Neil, Food and Nutrition Press, Inc., 265 Post Road West, Westport, CT 06880.

ENERGY CONSUMPTION FOR REFRIGERATED, CANNED, AND FROZEN SNAP BEANS AND CORN

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ABSTRACT

The energy inputs at different stages in the food cycle of corn and snap beans were estimated for refrigerated, canned, and frozen market forms. In the case of corn, the energy inputs totalled 3,146, 2,986, *and* 3,902 *Btu/*2.9 *oz serving for canned, frozen, and refrigerated market forms. The corresponding figures (Btu/*2.3 *oz serving) for snap beans were* 2,913, 2,715, *and* 2,134, *respectively. The difference between the magnitudes for the canned and frozen forms is not significant. Further, because of the variability in the energy data for the different stages in the food cycle, magnitudes of energy consumption different than those listed may be obtained. The present and earlier studies on vegetables show that edible yield (number of servings) plays a major role in the energy consumed in the total cycle. Based on the present and previously published studies on energy consumption for vegetables, it appears that raw or refrigerated vegetables with yields more than about* 40% *will require less energy than other market forms. In this context, while most raw vegetables have yields higher than* 40% *they have short storage lives. Therefore, a large number of vegetables must be frozen or canned for long term availability.*

INTRODUCTION

Recent studies have shown that energy inputs at all stages, from farm gate to consumption at home, must be considered to determine the energy consumption for a market form of a commodity (Henig and Schoen 1976; Olabode *et al.* 1977; Rao 1977). Studies of this nature are useful for determining market forms that require less energy than others. Henig and Schoen (1976) and Rao (1977) showed that for corn and peas the energy consumption for the canned and frozen forms was nearly the same.

Olabode *et al.* (1977) and Rao (1977) considered the yield (edible portion) of each market form in their studies by expressing their results on a per serving basis. In the case of vegetables, the yield of the raw form varies with the commodities (Matthews and Garrison 1975). Also, for commercial distribution, some of the vegetables require storage and transportation at low temperatures and high humidities so that one is dealing with a refrigerated form for energy studies (Rao 1977).

Olabode *et al.* (1977) found that the raw form required the least amount of energy to produce mashed potatoes. However, in the case of boiled peas the refrigerated form required as much energy as the canned and the frozen forms (Rao 1977). The latter result is of interest because it shows that the non-processed (raw or refrigerated) form may not be the least energy intensive option for all vegetables. It would be desirable to point out the vegetables whose raw form will require minimum energy per serving.

In this study, the energy consumption per serving of boiled corn kernels and snap beans was estimated for refrigerated, frozen, and canned forms. These estimates confirmed the important role of yield (number of servings) on energy consumption for vegetables observed in earlier studies (Olabode *et al.* 1977; Rao 1977). Another objective of the study was to utilize data on yields (Matthews and Garrison 1975) and energy consumption to identify the vegetables whose raw form will require less energy than other market forms. The final objective was to identify the vegetables that must be processed for availability over long term periods utilizing data on storage life compiled by Lutz and Hardenburg (1968).

MATERIALS AND METHODS

The steps in the food cycle of refrigerated, canned, and frozen snap beans and corn are similar to those for peas (Rao 1977) and hence will not be discussed here. The energy consumption in most of the steps was also determined as described for peas. Here, only the methods that are different are discussed. For the benefit of the reader, the important conversion factors, assumptions, and other data are given in Table 1. It will be emphasized that the number of servings listed in Table 1 were calculated from the yield data of Matthews and Garrison (1975) and the serving size data of Sweeney *et al.* (1962). For each market form of a vegetable, the number of servings is directly proportional to the yield.

Energy Consumption in Processing Plants

Energy consumption in freezing and canning plants was determined

Table 1. Conversion factors, assumptions, and other data employed in the study

Energy units: Btu's of fossil fuels.

Basis: one 2.3 oz serving of boiled snap beans and one 2.9 oz serving of boiled corn kernels (Sweeney *et al.* 1962).

Number of servings per 1 lb of each market form[a]:

	Beans	Corn
Canned	3.9	3.6
Frozen	6.1	5.3
Refrigerated	6.0	2.1

Electricity, 1 kwh = 11,600 Btu.

Fossil fuels: standard calorific values.

Transportation distances and modes:

Farm to processing plant: 50 miles, truck.
Plant to warehouse: 1,200 miles; 60% train, 40% truck.
Warehouse to retail store: 70 miles, truck.

Train speed: 45.5 mph.

Truck speed: Intercity, 40 mph; in-city, 19 mph (Dwyer *et al.* 1977).

Residence times in storage:

Commercial warehouse: 6 mos.
Retail warehouse: 2 mos.
Supermarket, frozen: 1 week.
Supermarket, refrigerated: 5 days.
Home, frozen: 2 weeks.
Home, refrigerated: 5 days.

[a]Obtained by combining yield data from Matthews and Garrison (1975) and serving size data from Sweeney *et al.* (1962).

from data tabulated in a study for the Federal Energy Administration (now U.S. Dept. of Energy) (Anonymous 1974). These data were collected from a large number of plants and represented an average for the entire nation.

For the refrigerated form, the energy required to cool the vegetables after harvesting from 80° F to 40° F was estimated for a hypothetical plant with a capacity of 20 tons/day. The heat to be removed is the sum of the sensible heat and the heat of respiration (Lutz and Hardenburg 1968). A hydrocooler (24 ft × 9 ft × 2.5 ft), described by Ryall and Lipton (1972), was assumed to be suitable. Other assumptions included: (1)

water, cooled once from 70° F to 36° F, was used all day; (2) a pump with a 1.5 hp motor was used to circulate the cold water; (3) the efficiency of electricity use by the pump was 75%; and (4) the overall efficiency of electricity use by the refrigeration system and the heat exchanger to cool water was 25%.

Energy for Storage in Warehouses

Energy consumption for commercial warehouse and retail warehouse storage of canned and frozen beans was estimated as reported earlier (Rao 1977). Storage times of 6 months and 2 months were assumed in the commercial and retail warehouses, respectively.

For refrigerated forms the energy requirements were based on a central warehouse which handled the beans and corn, and packaged them in trays (Karitas 1969). Karitas (1969) showed that beans and corn make up 15% and 5% of the movement in a central warehouse, respectively. In contrast to beans and corn, refrigerated peas make up a very small portion of fresh market fruits and vegetables. For these reasons, while it was not necessary to consider a central warehouse for peas (Rao 1977) a central warehouse was included for refrigerated corn and snap beans.

The charges (rent, utilities, and insurance) in a warehouse handling 3 million packages of produce was estimated to be 0.31 cents per 1 lb package of beans and 0.21 cents for a package with 3 ears of corn (Karitas 1969). For computational purposes, 32% of the warehouse charges were assumed to be spent on utilities. The cost of the natural gas consumed was assumed to be equal to that of the electricity consumed. These utilities embrace all heating in winter, any lighting required, and also the cooling employed in the handling/storage space in the warehouse. From the costs in 1968 ($0.02/kwh of electricity and $0.253 for 1 million Btu for natural gas), the energy per serving of refrigerated beans and corn was estimated.

Energy for Preparation at Home

Energy consumed for the preparation of boiled snap beans and corn kernels at home for the three market forms was estimated from the experimental data obtained at the University of Maryland (Kramer 1978). In the experiments, triplicate cooking lots of the three market forms were employed. For the raw and frozen forms, 200 or 300 ml of water with added salt was brought to boil and a weighed quantity of the sample was added and cooked until tender. For the canned form, the liquid in the can was drained and brought to boil in a pan; to the boiling liquid the vegetable was added and heated.

Energy consumption data were obtained on an electric and a gas stove. The consumption of gas was measured with a gas meter (Wet Test Meter, Precision Scientific Co.) and that of electricity was measured with a wattmeter (Model AR 542, Type I-30-S, General Electric Co.); the cooking time was also recorded.

The experimental data were corrected for the efficiency of generation of electricity (1 kwh = 11,600 Btu) and the distribution of gas and electric stoves: 47% electric and 53% gas (Newman and Day 1975).

Waste and Package Disposal

Energy expended for the disposal of inedible wastes from refrigerated snap beans was estimated as described earlier (Rao 1977). For refrigerated corn, the inedible portions (husks, silk, and cob) are large enough to be disposed as solid waste. The energy use for disposing the inedible waste and packages was estimated from the respective weights and that 155 Btu are required to dispose 1 lb solid waste (Berry and Makino 1974).

Energy for Dishwasher Operation

Energy consumption by dishwasher was estimated as described previously (Rao 1977) to be 30 Btu for snap beans and 116 Btu for corn. While the method correctly predicts the same value for the three market forms of each commodity, there is no justification for the different values for the two commodities. It seems that at the present time there is no equitable method for determining the energy for dishwasher on the basis of a serving of the vegetables. For this reason, the energy consumed for dishwashing was omitted from the total estimates.

RESULTS AND DISCUSSION

The energy consumption at each stage of the food cycle of corn and snap beans is given in Tables 2 and 3, respectively. The total energy consumption for corn was 3,146, 2,986, and 3,902 Btu/serving for the canned, frozen, and refrigerated forms, respectively. In the case of snap beans, the energy consumption was 2,913, 2,715, and 2,134 Btu/serving for canned, frozen, and refrigerated forms, respectively.

In the case of the canned form, energy needs for packaging are high; they are higher than the energy input at any other stage in the food cycle. In the distribution sector, energy for transportation and environmental control are the major inputs. For the refrigerated form, top ice required (Ashby 1970; Redit 1969) to maintain the low temperature and high hu-

Table 2. Energy consumption per serving of canned, frozen, and refrigerated corn

Operation or Segment	Energy Input/Serving Canned	Frozen	Refrigerated	Sources of Data
Corn to cooling plant	NA[a]	NA	30	Round trip 50 miles by truck; energy data of U.S. Dept. of Transpn. (1974). Waste data of Katsuyama *et al.* (1973).
Corn to processing plant	35	35	NA	
Processing and in-plant storage	843	590	443	Data of Anon. (1974) and a model plant for refrigerated corn.
Packaging				
Can, label, and glue	1,458	NA	NA	Derived from Hoddinott (1975), Berry and Makino (1974), Payne (1975), Ryall and Lipton (1972).
Carton and paper	NA	323	NA	
Wire bound crate, paper board, and plastic film	NA	NA	390	
Box for cartons and cans	130	88	NA	
Distribution				
Plant to retail warehouse	241	164	414	Distance of 1,200 miles between plant and retail warehouse; 60% by rail and 40% by truck; data from U.S. Dept. of Transpn. (1974), Dwyer *et al.* (1977), Kuenzli (1962), and industry sources. Distance is 70 miles between warehouse and store; transportation by truck.
Environmental control in transit	NA	17	53	
Warehouse to supermarket	25	17	42	
Environment control in transit	NA	2	4	

[a]NA means not applicable.

(continued)

Table 2. Energy consumption per serving of canned, frozen, and refrigerated corn (cont.)

Operation or Segment	Energy Input/Serving Canned	Frozen	Refrigerated	Sources of Data
Distribution (cont.)				
Commercial warehouse, 6 mos.	14	79	NA	Data of Henig and Schoen (1976a) for frozen foods and Rao *et al.* (1976) for canned beans; data of Karitas (1969) for refrigerated corn.
Retail warehouse, 2 mos.	5	26	NA	
Central warehouse	NA	NA	472	
Marketing				
Freezer, 1 week	NA	632	NA	Data from refrigeration industry, Beatty (1975), and *Supermarket News'* distribution study (1976).
Refrigeration; 3 days; packages four deep	NA	NA	738	
Heating, lighting, and air-conditioning	123	158	122	
Store packaging (paper bag)[b]	—	—	—	
Shopping				
Travel by car[b]	—	—	—	
Home storage				
Freezer, 2 weeks	NA	410	NA	Data from Newton (1976); Newman and Day (1975).
Refrigerator, 3 days	NA	NA	229	
Home preparation				
Gas and electric ranges	264	442	918	Data from Sweeney *et al.* (1962); Newman and Day (1975); Kramer (1978).

[b]Energy for this item is also important, but an equitable method of apportioning is not available at the present time. *(continued)*

Table 2. Energy consumption per serving of canned, frozen, and refrigerated corn (cont.)

Operation or Segment	Energy Input/Serving			Sources of Data
	Canned	Frozen	Refrigerated	
Waste and package disposal				
Package disposal	8	3	3	Data from Berry and Makino (1974), Midwest Research Institute (1974), Newman and Day (1975), Watt and Merrill (1963).
Dishwasher [b]	—	—	—	
Inedible waste disposal	NA	NA	44	
Total (Btu/serving)	3,146	2,986	3,902	

[b]Energy for this item is also important, but an equitable method of apportioning is not available at the present time.

Table 3. Energy inputs for canned, frozen, and refrigerated snap beans[a]

Operation or Segment	Energy Input/Serving		
	Canned	Frozen	Refrigerated
Snap beans to cooling plant	NA[b]	NA	11
Snap beans to processing plant	12	12	NA
Processing and in-plant storage	777	512	177
Packaging			
Can, label, and glue	1,346	NA	NA
Carton and paper	NA	280	NA
Bushel basket, paper board, and plastic film	NA	NA	206
Box for carton and cans	120	76	NA
Distribution			
Plant to retail warehouse	223	143	145
Environmental control in transit	—	12	22
Warehouse to supermarket	23	15	15
Environment control in transit	—	2	1
Commercial warehouse, 6 mos.	13	69	NA
Retail warehouse, 2 mos.	4	22	NA
Central warehouse	—	—	375
Marketing			
Freezer, 1 week	NA	560	NA
Refrigeration; 5 days; packages three deep	NA	NA	360
Heating, lighting, and air-conditioning	128	178	101
Store packaging (paper bag)[c]	—	—	—
Shopping			
Travel by car[c]	—	—	—
Home storage			
Freezer, 2 weeks	NA	364	NA
Refrigerator, 5 days	NA	NA	97
Home preparation			
Gas and electric ranges	259	467	605
Waste and package disposal			
Electric waste disposer	NA	NA	2
Package disposal	8	3	3
Dishwasher[c]	—	—	—
Wastewater treatment[d]	NA	NA	14
Total (Btu/serving)	2,913	2,715	2,134

[a]Sources of data as in Table 2, except for wastewater treatment.
[b]NA means not applicable.
[c]Energy for this item is also important, but an equitable method of apportioning is not available at the present time.
[d]Energy for wastewater treatment as in Rao (1977).

midity is a major contributor to the energy consumed.

The warehouse energy usage per unit weight of refrigerated form is higher than for frozen form partly because of the low throughput of refrigerated packages (3 million) per year (Karitas 1969) which necessitates operation at less than optimum condition. In contrast, one warehouse for frozen foods was found to handle as many as 239 million pounds of frozen foods per year (Rao 1977). On the other hand, the mean storage time for refrigerated form is only a few days; whereas, for frozen form the storage time is 6 months.

Comparison of Studies on Corn

Brown and Batty (1976) and Henig and Schoen (1976) estimated energy consumption for corn; the former studied the canned form while the latter studied frozen and canned forms. Energy consumption for refrigerated corn has not been reported thus far. Because of different data bases and assumptions, complete agreement cannot be expected between this study and the above studies. In the following, some similarities and differences among the three studies are discussed.

First, it must be emphasized that the more detailed studies will indicate higher energy inputs. Furthermore, in this study sources of data that became available only recently have been used. For example, data on energy consumption in supermarkets (Gerke 1976) became available after the studies of Brown and Batty (1976) and Henig and Schoen (1976) were completed.

Brown and Batty (1976) included energy for agricultural production, shopping, and dishwashing. Subtracting the energy inputs of the said stages results in an estimate of 11,830 per lb of canned corn or 3,286 Btu/serving. This figure is not too different from 3,146 Btu/serving estimated in this study. Some features common to the two studies are the distances assumed: 1,441 miles by Brown and Batty (1976) and 1,320 miles in the present study; energy intensiveness of 2,667 Btu/ton-mile for trucks by Brown and Batty (1976) and 2,540 Btu/ton-mile in the present study.

Nonetheless, there are several differences. Brown and Batty (1976) assumed that only direct energy inputs are sufficient for estimating energy for cans. The result is that their estimate is lower than the figures used by Henig and Schoen (1976) and in the present study. Brown and Batty (1976) assumed trucking to be the only transportation mode. They also do not provide details on the energy estimate for home cooking, which is lower than in the present study.

The energy estimates of Henig and Schoen (1976) for canned and frozen corn are lower than those of the present study. In the study of Henig and Schoen (1976), the distances assumed in the distribution sector are not clearly stated for possible check of their computations. Further, for canned corn, the energy for processing was taken as 2,242 Btu/lb instead of 3,034 Btu/lb. They have used the data for raw vegetables excluding tomatoes instead of data for processed vegetables excluding tomatoes (Anonymous 1974). Some steps in the food cycle, such as package disposal, were not considered. Nevertheless, the study of Henig and Schoen (1976) is a major effort and perhaps the first to point out that energy for foods must be estimated over the total food cycle.

Finally, we note that Henig and Schoen (1976) concluded that the energy for 1 lb frozen corn is about 13% higher than for 1 lb of canned corn. Our estimates on a 1 lb retail unit basis indicate that the frozen form is 40% more energy intensive than canned, but on a per serving basis it is less energy intensive than canned form. The data of Henig and Schoen (1976) when expressed on a per serving basis (3.6 servings for canned and 5.3 for frozen) also show that frozen corn is less energy intensive than canned corn.

Comparison of Energy for Corn and Snap Beans

For the total food cycle (Table 2), energy per serving of frozen corn is less than for canned and refrigerated market forms. Refrigerated corn requires the highest energy per serving among the three market forms studied. The chief reason is the large quantity of inedible waste that is part of the refrigerated corn throughout the food chain and that results in only 2.1 servings per lb of retail unit. Further, refrigerated corn is available for only 8 days after harvest.

In contrast to corn, for the total food cycle of snap beans (Table 3), energy per serving of frozen beans is less than for canned but higher than for the refrigerated form. However, refrigerated beans are available for only about 10 days after harvest. In contrast, canned and frozen forms have a shelf life of over a year.

Electricity is used to a greater extent for frozen and refrigerated market forms. In this regard, the assumption of 11,600 Btu/kwh which accounts for the low efficiency of generation and transmission of electricity heavily penalizes refrigerated and frozen market forms. Methods of electricity generation, other than with fossil fuels, which have a higher efficiency will indicate lower consumption by the two market forms.

Yield from Vegetables and Minimum Energy Market Forms

As pointed out earlier, the number of servings of a market form is directly proportional to the yield. The key role of yield on energy consumption in the total cycle of a commodity can be seen from the present and earlier studies (Olabode *et al.* 1977; Rao 1977). Raw potatoes and refrigerated snap beans, which have high yields, require the least energy among different market forms. In contrast, for relatively low yielding peas and corn, the refrigerated form requires more energy than the canned and frozen forms. Finally, on a per serving basis, frozen beans, corn, and peas are less energy intensive than their canned forms, primarily due to the higher number of servings possible per comparable retail units.

The above observations regarding the role of yield will be applicable to other vegetables also. The yields of canned and frozen forms of vegetables do not differ significantly from those of corn, snap beans, and peas studied thus far. In the case of the raw form, the yields vary over a wide range. With the exception of few vegetables such as carrots, beets, and potatoes, raw vegetables in general require the same storage conditions as peas, corn, and snap beans.

It would be desirable to identify the vegetables whose raw form will consume minimum energy in the total cycle per serving (METC). For this purpose, in Fig. 1 the yields (%) of several vegetables (Matthews and Garrison 1975) are plotted against the minimum storage life in days (Lutz and Hardenburg 1968). The vegetables that have been the subject of the present and recent studies (Olabode *et al.* 1977; Rao 1977) are identified with an asterisk.

In Fig. 1, snap beans and potatoes, whose raw (or refrigerated) forms require METC, are located on the right hand side. In contrast, peas and corn, whose raw forms do not indicate METC, are on the left hand side. The energy consumption for refrigerated corn is much higher than the canned and frozen forms. In contrast, the energy consumption for refrigerated peas was only slightly higher than for canned and frozen forms (Rao 1977). From these observations and the yields of raw corn and peas, it appears that raw vegetables with yields higher than about 40-45% will be the minimum energy market forms. In Fig. 1, the raw forms of the vegetables to the right of the vertical line will have METC.

A second and rather obvious constraint to the use of raw vegetables on a commercial scale is the minimum storage life. A substantial number of vegetables have a minimum storage life of 10 days (horizontal line in Fig. 1) or less. This means a major portion of these vegetables must be processed for long term availability to consumers. Finally, the vegetables well above the horizontal line and to the right of the vertical line in Fig. 1 can be marketed in the raw form with minimum use of energy for sixty days or more depending on the commodity. These vegetables are: beets, carrots, globe onions, potatoes, pumpkins, and sweet potatoes.

The above discussion is based on energy consumption, yield, and shelf-life data. It is implicitly assumed that the raw vegetables are harvested

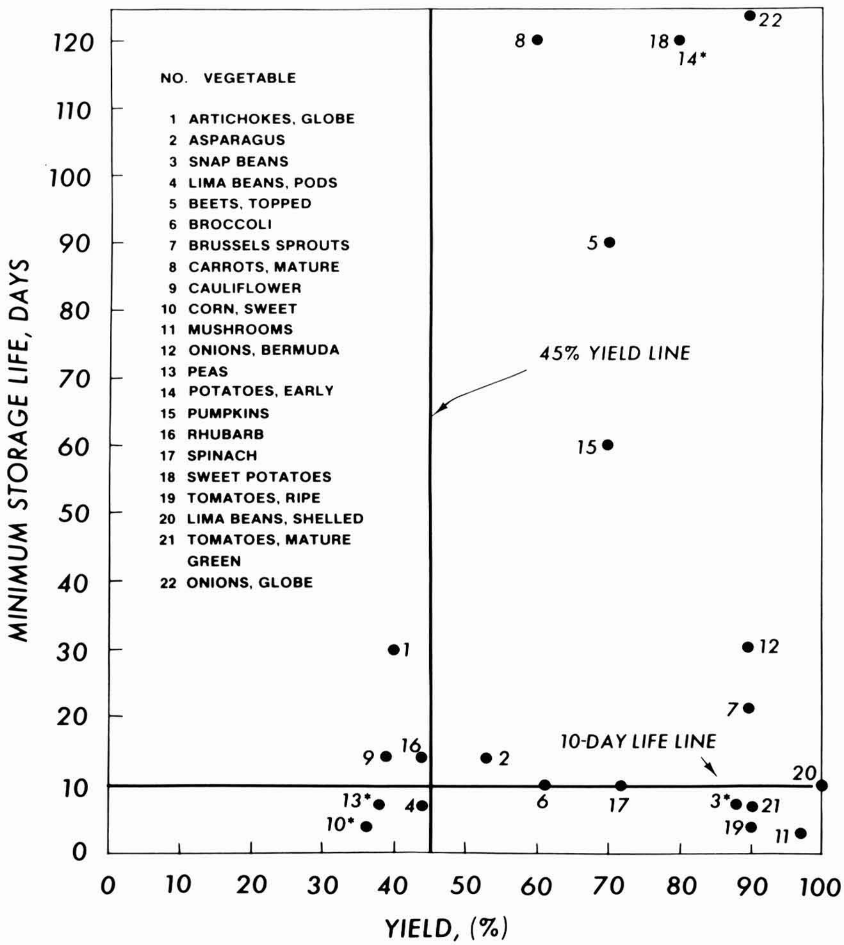

FIG. 1. PLOT OF YIELD (%) VS MINIMUM STORAGE LIFE (DAYS)

Numbers refer to vegetables listed; numbers with asterisks indicate vegetables that were subjects of energy studies. Globe onions have a minimum life of 180 days. Vertical line indicates the minimum yield for raw vegetables to be the least energy intensive form. Horizontal line indicates a minimum shelf-life of 10 days.

and handled with care so that the tabulated yields and shelf lives are attainable. The observations regarding minimum yields and energy consumption are applicable for commercial distribution of raw vegetables; they may not be relevant to home gardens. It must be noted that consumer selection of a market form is based on a variety of reasons such as personal preference, price, availability, sensory attributes, and retained nutrients.

In this study, vegetables packed in retortable pouches were not considered because reliable data on yields and energy consumption in processing plants were not available readily. Also, vegetables processed in retort pouches do not constitute as large a portion of the market as canned or frozen vegetables. Even if vegetables processed in retort pouches are less energy intensive than canned and frozen forms, the conclusions regarding the yield-energy consumption relationship for raw vegetables will not be affected.

CONCLUDING REMARKS

Energy consumption per serving in the total food cycle of corn and beans was different for canned, frozen, and refrigerated market forms. The difference between the energy consumption for the canned and frozen forms was not significant. Because of the variability in the energy data for each stage in the food cycle, magnitudes of energy different from those estimated in this study may be obtained. However, the data and the methods employed in this study are believed to be unbiased to any market form.

Energy consumption per serving of a vegetable is inversely proportional to the number of servings per retail unit. In turn, the number of servings is proportional to the yield. It appears that raw or refrigerated vegetables with yields higher than about 45% require less energy per serving than the canned or frozen market forms.

Most vegetables have a minimum storage life of 10 days or less and hence must be either canned or frozen for long term availability. However, beets, carrots, globe onions, potatoes, pumpkins, and sweet potatoes have minimum storage lives more than sixty days; also, their yields are higher than 60%.

ACKNOWLEDGMENTS

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MECHANICAL CLEANING EFFECT AND PRESSURE DROP OF AIR-WATER-FLOW IN HORIZONTAL GLASS TUBES (VACUUM DAIRY PIPELINES)

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ABSTRACT

Mathematical models are presented which make it possible to calculate pressure drop and mechanical cleaning effect for plant design of vacuum dairy milking pipes. Experimentally, air-water mixtures were sent through a test plant, consisting of glass pipes 0.034 *m in diameter and* 60 *m in length (*93 *m in some experiments), where a soiled piece of pipe could be inserted without disturbing the flow. The soiling was milk-based and dried on application. Light absorption of the soiled glass tube was measured before and after the cleaning operation, which was performed for* 45 *s with plain water at room temperature. To calculate the pressure drop, the so-called Dukler constant-slip-method was used. A holdup correlation according to Hughmark was improved to fit the pipe system used.*

Through linear regression analysis an equation was obtained, describing the cleaning effect as influenced by the Reynold number and the liquid fraction of the air-water mixture.

INTRODUCTION

When a vacuum milking plant is to be designed, a knowledge of pressure drop and cleaning effect calculations is of value. A milking plant consists of numerous components with different pressure drop and cleanability characteristics. These differences are to a great extent due to the component geometry. Horizontal glass tubes, often used as milk pipelines, have a rather simple and symmetric geometry and thus served as a model for introductory research in this field.

The intention was to study the mechanical cleaning effect as related to certain flow characteristics. Therefore, the cleaning experiments were performed without added chemicals or elevated temperatures. It should be noted that these investigations deal with a continuous air and water supply only. A common practice is to use pulsed air as well, if cleaning conditions are otherwise unfavorable.

METHODS AND MATERIALS

Soiling of Glass Tubes

A mixture, with a dry matter content of 50% (wb) and a lipid content of 10% (wb), containing skim milk, water and whipping cream, was produced. One hour's swelling was allowed, before it was applied, in 3-5 equidistant strips with a volume of 0.1 ml per strip, to a rotating glass tube (0.25 m long and 0.034 m inner diameter). The location of each strip was fixed. The strips were dried with a warm air current for 5 min in the still rotating tube. The tube was finally dried in an oven at 100° C for 120 min and left overnight to cool down slowly.

Optical Measurement of the Soiling

Measurements of the light absorption of the strips were made before and after soiling and after the cleaning experiments. A light beam (visible light) was directed perpendicular to the glass tube wall at the location of the strip, and its intensity was registered on the opposite side with a photoelectric cell. For each strip, ten equi-distant measurements were made at random points around the tube. The photoelectric cell was calibrated in such a way that an absorption value of approximately 20 (on an arbitrary scale) was obtained for unsoiled tubes and approximately 900 for soiled tubes. The figures given here as the "cleaning effect" were calculated as the difference between the mean light absorption of the strips, as measured before and after the cleaning experiment.

Pressure Measurement

A pressure gage was used. The equipment, having a Bourdon tube of bronze, was manufactured to give a maximal deviation of 0.5% of the reading. The gage was in contact with the pipe system through a drilled hole (2 mm in diameter) in the pipe wall. This connection was throttled to improve readability of the pulsating pressure.

Fluid Flow Measurement

A variable area meter was used. It was calibrated to give an error of less than one percent. The airflow meter, registering directly the gas volume passing through a system of bellows, had an accuracy of 1.5%

according to the manufacturer.

Experimentals

Figure 1 shows the piping used for pressure drop and cleaning effect experiments. The short loop was used for all cleaning experiments and a major part of the pressure drop measurements. The distance from the point where the water was mixed with air to position 1 was approximately 4 m and from position 4 to the releaser, where also the vacuum was applied, was approximately 6 m. At position 5, where the soiled glass tube was to be inserted, there was a valve regulated by-pass system for the air-water mixture. The by-pass system was used to avoid disturbances of the flow when the glass tubes were changed. Time for the cleaning was 45 s at an air-water temperature of 22° C. The absolute pressure was measured at the positions shown in Figure 1. All pipes were made of glass with an inner diameter of 0.034 m. Each experiment was repeated at least three times.

Variables were water-flow and air-flow, which both could be varied independently within the limits given by the vacuum level in the releaser. The water was pumped into the system, and its flow rate was controlled by a valve. The air, which was sucked through the system, was throttled to control its flow rate. Water-flow was varied between 5 and 50 l/min and air flow between 25 and 670 l/min (air of atmospheric pressure).

Pressure Drop and Cleaning Effect Calculations

There are a large number of methods and correlations for the computing of two-phase pressure drop (De Gance and Atherton 1970, Govier and Aziz 1972). These authors, however, agree that, in the case of horizontal flow, the Dukler constant slip method is the most reliable theory. This is a homogenous flow model that, at a certain point, computes the pressure-gradient. An integration along the pipe is then made for the prediction of the total pressure drop. The use of a programable calculator is essential, as the expressions are in an implicit form and iterations have to be made.

As the Dukler method assumes different flow velocities for the gas and liquid phase, respectively, the volumetric fraction (λ) of each phase is not equal to the fraction based on the cross section area (in place holdup) (R) as there exist velocity and concentration profiles across the tube. An empirical holdup correlation has to be made. The so-called "Hughmark" holdup correlation (Hughmark 1962) was applied in accordance with the equation calculated by De Gance and Atherton (1970).

$$\overline{R}_L = 1 - (1 - \lambda_L) \cdot K \qquad (1)$$

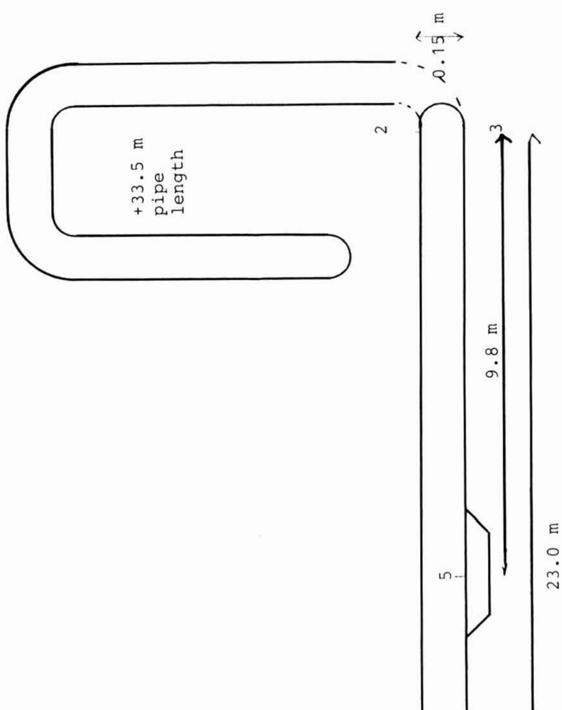

FIG. 1. DRAWING OF THE PIPING

Top view. All pipes are horizontal in the same level. Positions 1, 2, 3 and 4 are for pressure measurements and position 5 for inserting soiled glass tubes.

where

$$K = 0.75545 + 3.585 \cdot 10^{-3}\ \delta - 1.436 \cdot 10^{-5} \cdot \delta^2 \qquad (2)$$

and

$$\delta = f(\overline{R}_L) \qquad (3)$$

A description of the pressure drop computation is given in the appendix.

The empirical holdup correlation (2) was not specially computed for our system. An attempt was made to find a better equation. By a Simplex method (Shaw 1971), new coefficients were produced, through minimizing the mean of the relative errors of the calculated versus the measured pressure drop.

$$\text{Min} = \frac{\sum_{1}^{n} \left| \Delta P_{cal} - \Delta P_{meas} \right| / \Delta P_{meas}}{n} \qquad (4)$$

The Dukler constant-slip method gives a tool for calculating different flow properties at the exact position in the test plant where the cleaning of the soiled glass tubes was studied. Flow properties of interest are flow velocity, pressure gradient, Reynold number, holdup, and fluid quality (fraction of liquid or gas). Regression analysis (the step-wise method) (Draper and Smith 1966) was applied to find correlations between the cleaning effects (as calculated by the difference in light absorption before and after cleaning) and the flow properties of interest.

RESULTS AND DISCUSSION

Pressure Drop

The number of measurements was 212, of which 112 at room temperature and 100 at +45° C. All the cleaning experiments were performed at room temperature (22° C). Additional experiments at 45° C were made only for the pressure drop experiments. Use of the originally Hughmark holdup correlation equation gave a relative error in the pressure drop calculations of 24.9%, determined as the mean deviation (4).

The simplex-method for generating new holdup correlation coefficients gave:

$$K = 0.62601 + 5.5820 \cdot 10^{-3} \cdot \delta - 2.0899 \cdot 10^{-5} \cdot \delta^2 \qquad (5)$$

In this way the mean deviation (4) was lowered to 15.9%. Thus an improvement in the accuracy of the pressure drop calculations for the actual system was obtained. According to De Gance and Atherton (1970) the Dukler constant slip method using Hughmark's holdup correlation gives an accuracy in the calculated pressure gradient of 15-20%, so obtained results should be considered satisfactory. Single deviations larger than the mean values were not rare and those with a deviation of 50-60% appeared as can be seen in Fig. 2. Here the calculated versus the measured pressure gradients are drawn with the new holdup correlation (5) as a basis for calculations. In some cases the uncertainty, caused by the pulsating flow, in the measured pressures was large, which, to a certain extent, might explain these errors. It is also seen in Fig. 2 that there exists a number of so-called "outliers" but also that the errors do not seem to be normally distributed. These facts were the reasons for using (4) (L^1 norm) as the mathematical expression to be minimized and not the corresponding standard deviations (L^2 norm) (Cheney 1966). Generally we have the approximation (L^p norm).

$$\| f \|_p = \left(\int_a^b | f(x) |^p \, dx \right)^{1/p} \qquad (p \geqslant 1) \tag{7}$$

When computing the total pressure drop from the pressure gradient, an integration step of 1 m was found suitable since the computation time thus could be kept rather short. The error of the calculated pressure drop, as compared to those calculated with an integration step of 0.5 or 0.1 m, was neglible in these experiments.

Cleaning Effect

Correlations were tested for all possible linear combinations of the above mentioned flow properties (including their squares and logarithms). The correlation shown in Table 1 is the one of those tested which is in the best agreement with experimental data. In Fig. 3 the measured pressure drop and cleaning effect data are presented. The equation is given below:

$$\text{Cleaning effect} = -1492 + 203.8 \cdot \ln \text{Re} - 2146 \cdot \lambda_L^2 \tag{6}$$

The multiple correlation coefficient R^2 (Table 1), showing the percentage of the variation explained by the model, is not very high. This might

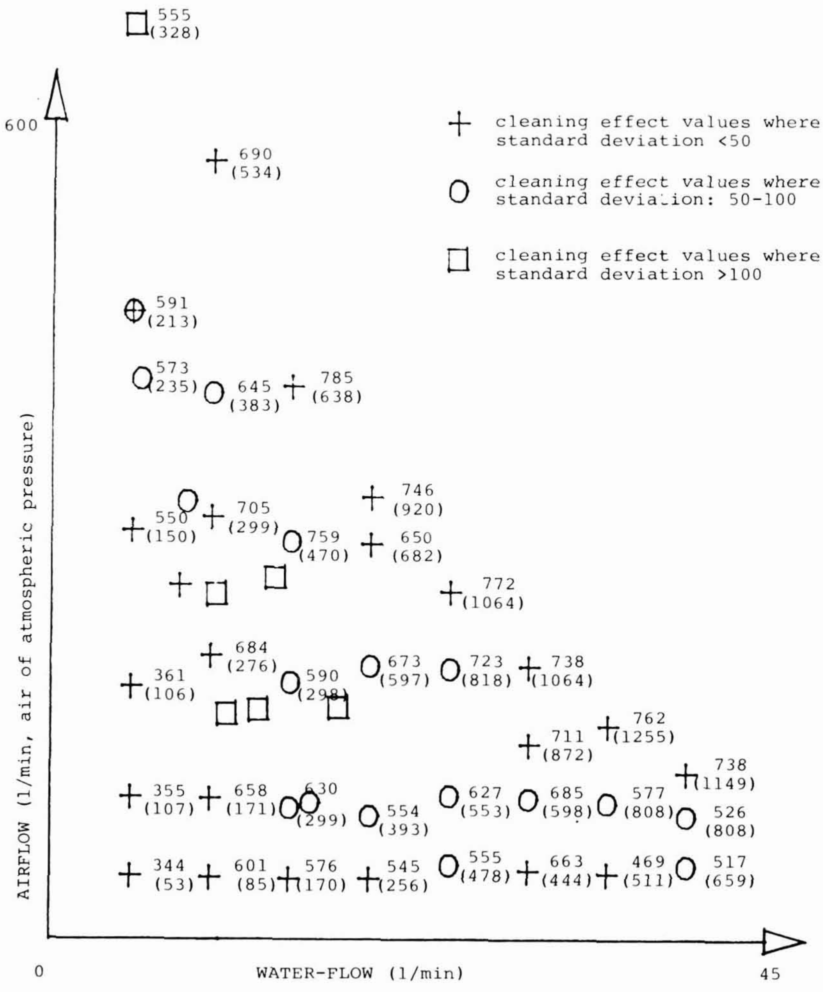

FIG. 2. EXPERIMENTAL MEAN VALUES OF MECHANICAL CLEANING EFFECT AND PRESSURE DROP

Figures in parenthesis represent the pressure gradient measured and those without parenthesis the cleaning effect.

Table 1. Cleaning effect related to certain flow characteristics. Results of regression analysis

Variable	Mean	Coefficient	Part. F-value
ln Re	10.48	203.8	244
λ_L^2	0.015	−2146.	56.1
Cleaning effect	612		

Intercept = −1492
R^2 = 0.659
Total F-value = 127
Standard deviation = 75 or, expressed as % of the mean = 12%
Number of cases = 135

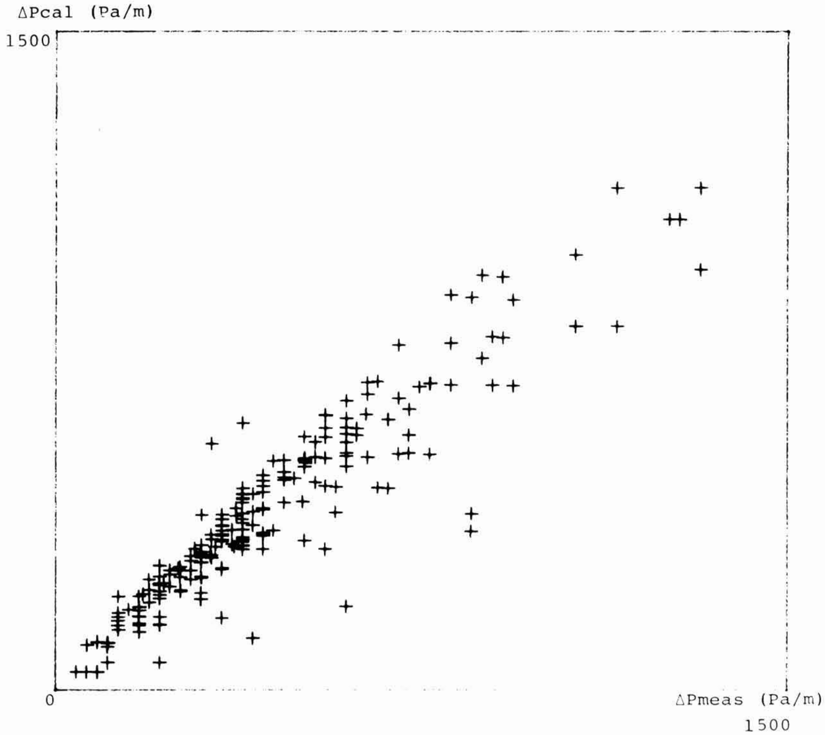

FIG. 3. CALCULATED PRESSURE GRADIENT VERSUS MEASURED PRESSURE GRADIENT BASED ON THE IMPROVED HOLDUP CORRELATION

be interpreted as if the obtained model was not suited for its purpose. However, considering the uncertainty in cleaning effect measurements (coefficient of variation = 8.9%) as compared to the corresponding value of the model (12%), it is reasonable to believe that this model will give values with an accuracy not very much less than those measured. The F-values are high, which means that there are no reasons for rejecting the model.

Figure 4 shows equi-cleaning-effect- and equi-pressure-drop-lines computed from the correlations obtained (5) and (6). In the different areas of air and water flow investigated, we found a different correlation between the pressure gradient and the cleaning effect. In certain areas, the lines are almost parallel, while in others they cross. These findings are of a great practical importance in plant design. A certain system working in the area where the lines are almost parallel have a cleaning effect that is insensitive to variations in liquid flow and corresponding air flow, whereas this is not the case in the other areas.

Shearing forces at the tube wall, varying with time are supposed to be of major importance for the removal of soiling. If this is the case, there seems to be a discrepancy between the pressure drop caused by the wall shearing forces and the total pressure drop as interpreted by the models (5) and (6). This is more pronounced in the slug flow regime, as can be seen in Fig. 4. This is the region where, as mentioned, the lines cross. The turbulence in the slug flow is causing a pressure drop that is partly useless for soiling removal, thus rendering the process less effective. This behavior is expressed mathematically by the fluid quality factor (λ) in Eq. (6).

However, we do not know if the removal of the soiling is directly proportional to the wall shearing force, since we know very little of the forces that keep the soiling together and adhere it to the tube wall.

The logarithmic dependence of the Reynolds number as the dominating factor in the obtained Eq. (6) could be due to the cleaning effect measurement method used. It should be noted that in the light absorption measurements of the soiled glass tubes, not only pure light absorption was measured; the light was scattered, since the soiling contained suspended particles.

These explanations, however, are only possible guesses. More detailed studies are needed to explain the dynamics of soiling removal in a two-phase system. Even in the case of a single phase system, many soiling removal phenomena, influenced by flow conditions, are unknown or determined on purely empirical basis. Results of Timperley and Tamplin in Jowitt (1980) are examples.

Model experiments are needed for single-phase and two-phase systems,

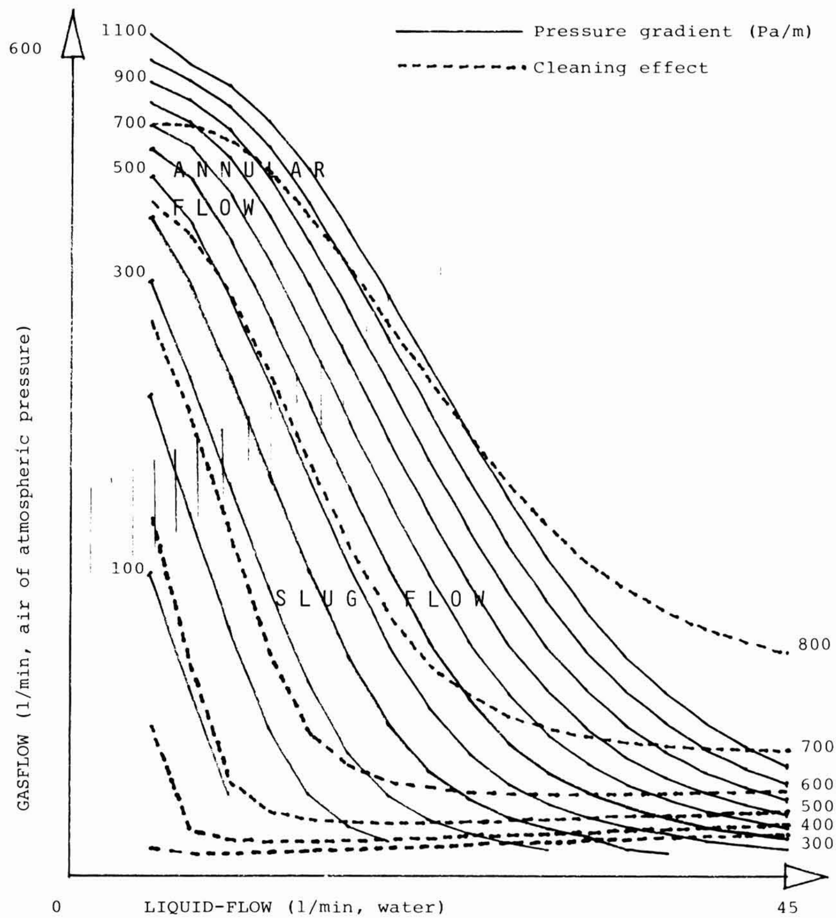

FIG. 4. PRESSURE GRADIENT AND MECHANICAL CLEANING EFFECT COMPUTED AS FUNCTIONS OF GAS- AND LIQUID-FLOW FROM OBTAINED CORRELATIONS

The air is expanded through pressure drop to twice its atmospheric volume. Tube diameter = 0.034 m.

so that the mechanisms at the surfaces between the wall, the soiling and the fluid (the boundary layer) can be studied.

SYMBOLS

A	cross sectional area of the tube, m^2
AC	flow acceleration correcting term
B	constants in the equation for the Hughmark holdup correlation
D	the diameter of the tube, m
f	friction factor of flowing fluid
G	mass flow rate, $kg/s \cdot m^2$
g	gravity, m/s^2
K	the Bankoff K-factor
P	absolute local pressure, Pa
Q	volumetric flow rate, m^3/s
R	inplace holdup
$\overline{R}$	average inplace holdup
Re	Reynolds number, two-phase with constant slip
Z	coordinate along the tube axes, m
υ	flow velocity, m/s
λ	flowing volume holdup, fraction
μ	viscosity, $kg/m \cdot s$
ρ	density, kg/m^3
τ	pressure gradient of frictional contributions, Pa/m
$C, f_o, \alpha, (\lambda), \xi, \delta$	are all parameters defined

SUBSCRIPTS

cal	calculated
cs	constant slip
G	gas
L	liquid
meas	measured
ns	no slip
SG	superficial gas
SL	superficial liquid
T	total
tp	two-phase constant slip

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All computation was performed at Lund Computer Central, Lund University, Lund, with their UNIVAC-1108 in FORTRAN V.

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APPENDIX

Method Used for Pressure Drop Calculation

To calculate the pressure gradient at a certain location of a horizontal tube you have to know the volumetric flow rates of the liquid and gas apart from their physical properties (density, viscosity, pressure). First you compute the holdup which is an iterative procedure:

$$C = \frac{1.7838 \cdot \upsilon_{ns}^{1/2} \cdot G_T^{1/6} \cdot D^{1/24}}{g^{1/8} \cdot \upsilon_{SL}^{1/4}}$$

$$\delta = \frac{C}{(\overline{R}_L(\mu_L - \mu_G) + \mu_G)^{1/6}} \quad \text{for } \delta > 10$$

$$K = B_o + B_1 \cdot \delta + B_2 \cdot \delta^2$$

$$\overline{R}_L = 1 - (1 - \lambda_L) \cdot K$$

where

$$\nu_{ns} = (Q_L + Q_G)/A$$

$$G_T = G_L + G_G$$

$$\upsilon_{SL} = Q_L/A$$

$$\lambda_L = \frac{Q_L}{Q_L + Q_G}$$

The pressure gradient is given as:

$$\frac{\partial P}{\partial Z} = - \frac{(\tau_f)_{cs}}{1 - AC_{cs}}$$

where

$$\left[AC_{cs} = \frac{1}{P} \quad \frac{G_L \cdot \upsilon_{SL}}{\overline{R}_L} + \frac{G_G \cdot \upsilon_{SG}}{\overline{R}_G} \cdot \left(1 - \frac{\overline{R}_L}{\overline{R}_G} \right) \right]$$

and

$$(\tau_f)_{cs} = \frac{f_{tp} \cdot G_T^2 \frac{\rho_{cs}}{\rho_{ns}}}{2 \cdot \rho_{ns} \cdot D}$$

$$f_{tp} = f_o \cdot \alpha (\lambda_L)$$

$$f_o = 2\left[{}^{10}\log \left(\frac{\text{Re}}{4.5223 \cdot {}^{10}\log \text{Re} - 3.8215} \right) \right]^{-2}$$

$$\alpha(\lambda_L) = 1.0 - \frac{\ln \lambda_L}{\xi}$$

$$\xi = 1.281 + 0.478 \ln \lambda_L + 0.444 (\ln \lambda_L)^2 +$$

$$+ 0.094 \cdot (\ln \lambda_L)^3 + 0.00843 (\ln \lambda_L)^4$$

$$\rho_{ns} = \rho_L \cdot \lambda_L + \rho_G (1 - \lambda_L)$$

$$\rho_{cs} = \rho_L \left(\frac{\lambda_L^{\,2}}{\overline{R}_L} \right) + \rho_G \cdot \frac{(1 - \lambda_L)^2}{1 - \overline{R}_L}$$

$$\mu_{cs} = \mu_L \cdot \lambda_L + \mu_G (1 - \lambda_L)$$

The two-phase Reynold number for constant slip is defined as:

$$\text{Re} = \frac{\rho_{cs} \cdot D \cdot \upsilon_{ns}}{\mu_{cs}}$$

Numerically the integration along the tube was linear and you obtain the pressure in the point $Z + \Delta Z$ as:

$$P_{z+\Delta z} = P_z + \left(\frac{\partial P}{\partial Z} \right)_z \cdot \Delta Z$$

All constants are assuming S.I. units.

KINETICS OF THERMAL INACTIVATION FOR A PECTIC ENZYME IN SWEET CHERRY BRINES[1]

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ABSTRACT

The manufacturing of several sweet cherry products involves the use of calcium bisulfite brines and generates significant amounts of the brine for disposal. One of the primary concerns preventing the reclamation and reuse of these brines is the enzymatic softening of product caused by polygalacturonase enzymes that may be present in spent brine. The objective of this investigation was to evaluate the thermal stability of the polygalacturonase enzyme in cherry brine so that thermal inactivation processes can be designed.

The first-order rate constants to describe thermal inactivation of polygalacturonase in cherry brine were measured over a range of typical pasteurization temperatures (68° to 72° C). The results were used to characterize thermal resistance of the enzyme in terms of Z-value (8.4° C) and activation energy (271 kJ/mole). The thermal stability of the enzyme was maximum between pH 2.8 and 3.5 and at sugar concentrations above 12%. A pasteurization system for cherry brine should be designed with all of the thermal stability characteristics considered in order to assure maximum product quality.

INTRODUCTION

In the United States, the cherry brining industry has increased significantly since 1930 (Steel and Yang 1960). Between 40 and 45% of the total sweet cherry production is handled in a brine. In Michigan, 75% of the production is brine processing (Woodroof 1975). During the manufacture of maraschino and glacé cherries, the fruit is held in calcium bisulfite brine before processing.

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The spent cherry brine, which is normally discharged to a municipal sewage system or to local streams, is characterized as an important source of pollution (Beavers *et al.* 1970). The most important pollutants in the spent brine are: (1) soluble solids; (2) free and bound sulfur dioxide; (3) low pH; and (4) color (Soderquist 1971). Payne *et al.* (1969) reported that undiluted spent brine has chemical oxygen demand of 15,000 mg/liter. Such brine is approximately 500 times stronger than domestic wastewater (Soderquist 1971).

The high sulfur content of the brine (more than 4,000 ppm as SO_2) is directly related to very high chemical oxygen demand. The dissolved oxygen in the water is depleted by microbial growth, stimulated by the high levels of organics present and tends to create anaerobic conditions. This anaerobiosis is conducive to the growth of organisms, such as *Desulfovibrio sp.* (Mckinney 1962). These microflora generate hydrogen sulfide and other malodorous reduced sulfur compounds resulting in serious odor problems.

Chemical and physical methods for brine treatment have been discussed by Sapers (1975). The application of hydrogen peroxide for odor control of sweet cherry brining waste has been investigated (Gerrish 1975). Biological treatment of spent brine is impossible due to high concentration of sulfur dioxide. Wastewaters from the cherry pitting process however, were found to be highly treatable by aerobic biological treatment process (Mauldin *et al.* 1975).

Reclamation of spent brine for recycling has been proposed for the purpose of reducing the pollution problem. A process for brine reclamation was developed at Oregon State University (Soderquist 1971) and consists of the following units: (1) sand filters for suspended solids removal; (2) activated carbon contactors for pigment adsorption; (3) a pasteurization unit for polygalacturonase enzyme inactivation; and (4) a chemical reactor for adjustment of pH and SO_2 concentration.

One important problem in reuse of reconditioned brine is the polygalacturonase enzyme. If any portion of the brine is contaminated with the enzyme, the entire bulk stock of brine can become contaminated during the reclamation process (Beavers *et al.* 1970).

The polygalacturonase enzyme has not been detected in cherries. Investigations of Montmorency cherries (Al-Delaimy *et al.* 1966) and in several other varieties of fresh cherries (Steel and Yang 1960) indicated that cherries are free of polygalacturonase. Steel and Yang (1960) did indicate that softening of commercially brined cherries such as reported by McCready *et al.* (1954), was produced by the polygalacturonase enzyme which hydrolyzes the pectic substances of the fruit and leads to soft final product. The sources of the enzyme are microorganisms which gain access to the cherries after damage during the ripening period or microorganisms which enter the brine with stems and plant particles.

The activity of the enzyme in calcium bisulfite brine does not follow a definite pattern. It has been reported that the enzyme remained active in the brine for a period of only 13 to 25 days (Yang *et al.* 1960). On the other hand, commercial samples of brined cherries showed enzyme activity three months after brining, but was inactive after six months in brine (Beavers *et al.* 1970). Brekke *et al.* (1966) found active polygalacturonase enzyme in brine from softened commercially brined cherries after one year. Cherries brined the second year in this brine produced soft fruit.

Current results indicate that the degree of activity and the period of activity of polygalacturonase in cherry brine is not predictable. Any investigation on reclamation of brine must include tests for the detection of polygalacturonase which should be conducted on each lot of brine before it is reused. No extensive study of polygalacturonase in cherry brine has been conducted, and the investigation of the enzyme in different brines has remained a problem. Methods suggested for inhibition of polygalacturonase in cherry brines are: (1) using alkyl aryl sulfate (Steel *et al.* 1960); (2) adjusting pH in the range from 1.0 to 1.6 (Yang *et al.* 1960); and (3) increasing the concentration of calcium chloride in the brine (Brekke *et al.* 1966). None of the mentioned methods have found commercial application and the inactivation by heat has been proposed as the only feasible approach (Soderquist 1971; Waters *et al.* 1961; Sapers 1975).

In general, the objective of this investigation was to determine kinetic parameters required to describe thermal inactivation of polygalacturonase in sweet cherry brine. More specifically, the purpose of the investigation was to experimentally measure the influence of temperature, pH and brine composition on the rates of thermal inactivation for polygalacturonase enzyme.

METHODS AND PROCEDURES

A variety of methods have been developed for thermal destruction of bacterial spores. Stumbo (1955) described the most common methods. Techniques, employed for bacterial spore studies, may be used for studying other biological materials in their original form or after appropriate modification. The well-known thermoresistometer, for example, has been modified for study of vitamin destruction by heat (Mulley *et al.* 1975).

The thermal inactivation of polygalacturonase enzyme in cherry brines requires some alternative heating methods for evaluation. Preliminary experiments established that less than 60 s was required to reduce the enzyme activity by more than 90% at 70° C. The constant temperature water bath technique was used and was modified to overcome limitations associated with a single bath. One was set at a temperature above the holding temperature and was used for heating of the samples, while the second bath was set at the holding temperature and was used to maintain the desired temperature during an established holding period. More details on these procedures are given by Athanosopoulos (1976).

Purified commercial polygalacturonase enzyme (Pectinase[2]) was diluted in commercial cherry brines to obtain a concentration of 1 mg/ml. Samples of one ml of brine were placed in test tubes, 8 mm in diameter and 20 mm in length. The tubes were heated in the heating bath for a predetermined time before transfer to the holding bath. Samples were removed at time intervals and cooled in an ice water bath. Two drops from each sample were used for enzyme activity determination.

The "cup-plate" technique, developed by Dingle *et al.* (1953) and used by Beavers *et al.* (1970) and by Steel and Yang (1960) for cherry brines, was selected for enzyme activity estimation. The ingredients necessary for the gel formation were blended and the mixture was transferred to 1000 ml. Erlenmyer flasks before sterilization at 15 psig for 5 min in an autoclave. Fifteen ml of the liquid substrate were transferred to 15 × 85 mm Petri dishes and allowed to solidify. Small plastic collars (9 mm in diameter) were imbedded in the media to provide cup openings.

Two drops (each drop was approximately 0.065 ml) of brine from each sample were placed in each cup and the dishes were incubated for 20 h at 36° C. The substrate in the incubated dishes was covered with 2N hydrochloric acid and after 5 min a clear zone developed around the cup area. The diameter of the zone (including the cup) was converted to enzyme activity by using a standard curve. The standard curve was constructed by plotting the zone diameters obtained from a number of enzyme dilutions, ranging from 10 to .001 mg/ml, versus log of concentration.

RESULTS AND DISCUSSION

A. Influence of Temperature

1. Order of the Reaction — The order of the enzyme inactivation reaction was established by measurement of percent activities and plotting

[2] Pectinase is the trade name for Polygalacturonase from *Aspergillus niger* supplied by SIGMA Chemical Company, St. Louis, MO.

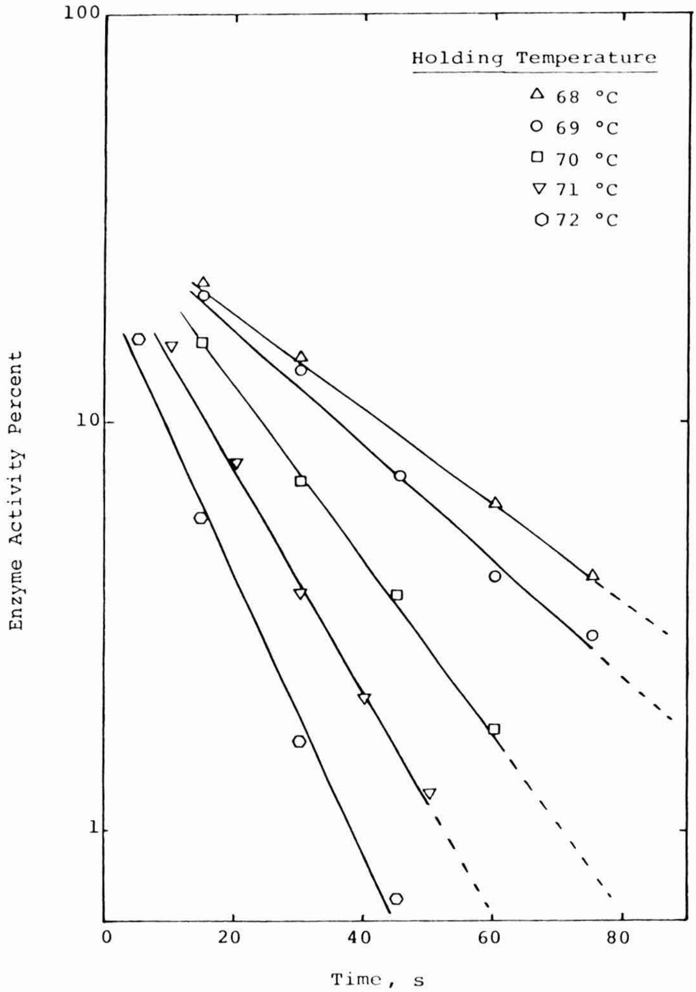

FIG. 1. EFFECT OF TEMPERATURE ON THE INACTIVATION RATE FOR THE POLYGALACTURONASE ENZYME IN CHERRY BRINE
(pH = 3.0)

versus time as illustrated in Fig. 1. Under the experimental conditions, the data fit to a straight line plot on semi-log coordinates represented a first order function. The influence of the temperature on the rate of enzyme inactivation is evident in Fig. 1. The straight lines were described by the following equation:

$$\mathrm{Ln}\ \frac{C}{C_o} = -\,kt \tag{1}$$

where C was the enzyme activity at time (t) and C_o was the initial enzyme activity, It should be noted that the higher temperatures resulted in higher rate constants (k) as indicated by steeper curves. The time scale in Fig. 1 corresponds to the heating time in the holding bath. The intercept of the curves with the percent activity indicates the enzyme activity at the time when the sample was transferred from the heating bath to the holding bath. As is evident, these values are below 100% since percent activity is expressed in terms of an initial enzyme activity as measured before heating was initiated.

2. **Rate Constants** — Equation (1) can be rewritten as follows:

$$C = C_o\, e^{-kt} \tag{2}$$

The enzyme activity indicated by the intercept should represent the initial activity (C_o). The inactivation rate constants were computed from Eq. (2) by using a least-squares fitting program for the Wang 2200 Computer. Figure 2 illustrates the normalized inactivation curves for three different temperatures. Table 1 presents the rate constants as they were evaluated by using the computer program. Computed values of the rate constant are similar to those found for thermal inactivation of polygalacturonase in cucumber brine. The rate constant in the latter case was found to be equal to 7.7×10^{-2} /s at 79.5°C, (Chavan 1976).

Figure 2 indicates that the experimental points are described well by the first-order functions for the inactivation process. The curves illustrated in Fig. 2 were obtained by using a least squares fit-power law function. Thus, the inactivation process tends to follow first order kinetics. This is supported by the high correlation coefficients presented in Table 1. The D-values (decimal reduction time) in Table 1 were computed from k-values using the following equation:

$$D = \frac{2.303}{k} \tag{3}$$

The D-values were plotted versus temperature on semilog coordinates. The straight line obtained and illustrated in Fig. 3 is referred to as the "thermal resistance curve". Using Fig. 3, the decimal reduction time (D) can be estimated for various holding bath temperatures. As the temperature increases, the D-value is reduced. The temperature change required for changing the D-value by 90% is called the "Z-value" and was found to

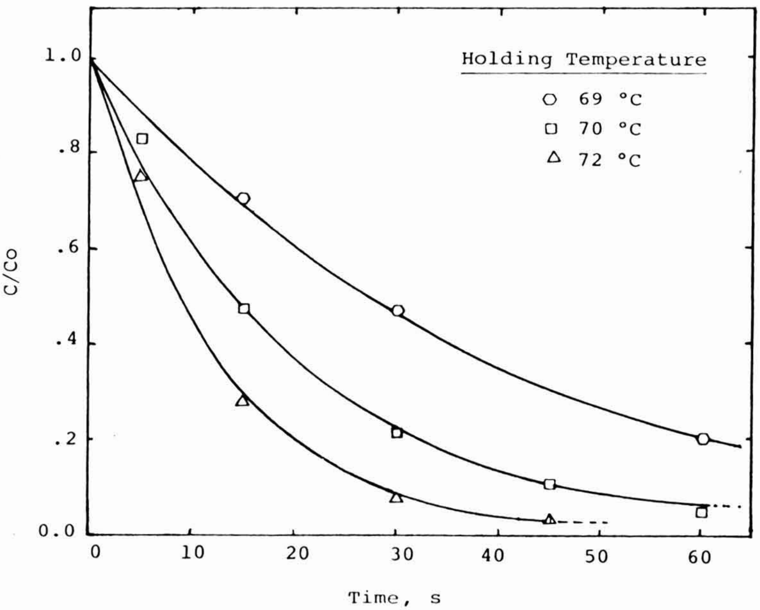

FIG. 2. NORMALIZED INACTIVATION RATE CURVES FOR POLYGALACTURONASE ENZYME IN CHERRY BRINE (pH = 3.0).

Table 1. Rate constants for inactivation of polygalacturonase in cherry brine (pH — 3.0) as influenced by temperature

Temperature (°C)	Correl.[1] Coeff.	$k \times 10^2$ (s^{-1})	D (s)
68	.9995	2.712	84.9
69	.9969	3.407	67.59
70	.9994	4.925	46.76
71	.9988	6.274	36.71
72	.9934	7.870	29.26

[1] For C/C_o versus time.

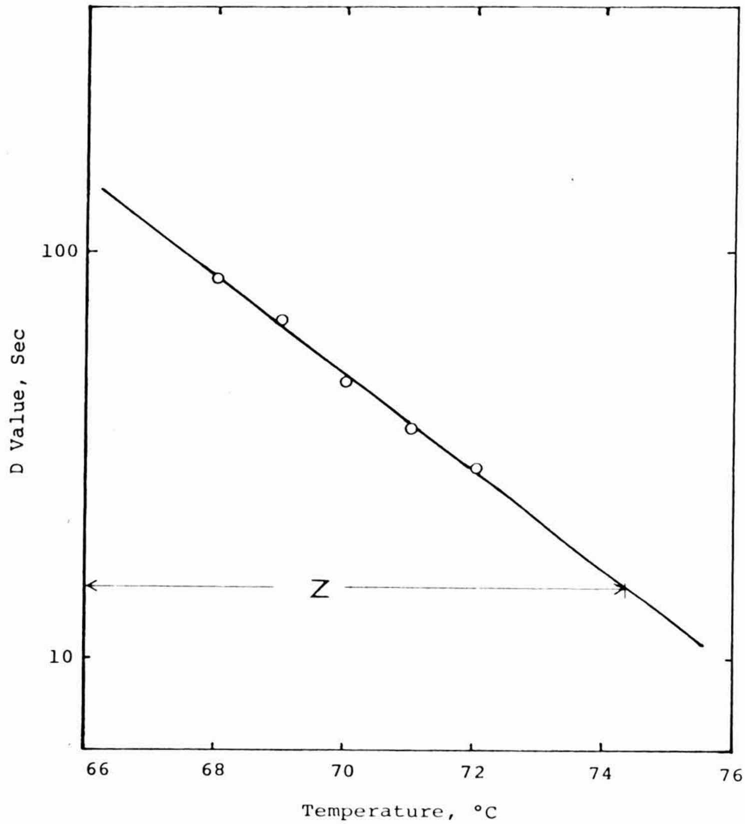

FIG. 3. THERMAL RESISTANCE CURVE FOR POLY-GALACTURONASE IN CHERRY BRINE (pH = 3.0).

be 8.4°C. The thermal resistance curve (Fig. 3) can be described by the equation:

$$\log D_1 = \log D_2 - \frac{T_2 - T_1}{Z} \tag{4}$$

or

$$D_1 = D_2\ 10^{\frac{T_2 - T_1}{Z}} \tag{5}$$

If the Z-value has been evaluated and the D-value is known at a given temperature, the decimal reduction time can be computed at any temperature.

3. **Activation Energy for Enzyme Inactivation** — An alternative manner to express the influence of temperature on the rate constant and/or the decimal reduction time is the Arrhenius equation:

$$k = A\, e^{(-E_a/RT_{ab})} \tag{6}$$

where k is reaction rate constant, A is a constant, E_a is the activation energy, T_{ab} is the absolute temperature, and R is the gas constant. Equation (6) can be written as follows:

$$\log k = \log A - E_a\ /\ (2.303)\ RT_{ab} \tag{7}$$

Equation (7) describes a straight line known as the "Arrhenius plot". The constant (A) is evaluated from the intercept, while the activation energy (E_a) is computed from the slope of the curve. The slope is equal to E_a/ (2.303) R. The slope of the Arrhenius plot, calculated with Wang Computer was found as:

$$\text{slope} = E_a / (2.303)\ R = 14{,}181.8 \tag{8}$$

and the activation energy was computed as:

$$E_a = 270.8 \text{ kJ/mole} \tag{9}$$

The activation energy for inactivation of polygalacturonase falls in the range generally accepted for inactivation of enzymes by heat. This range is from 210 to 630 kJ/mole (Messing 1975). The relatively small activation energy value verifies that the enzyme molecule has a very delicate and fragile structure (Segel 1975).

B. Influence of pH on Inactivation Rate

The enzyme inactivation rate was investigated at pH values of 2.5, 3.0, 3.5, and 4.0 at a temperature of 69° C. Commercial brine from Napoleon cherries was used in the experiment.

Data obtained from the experiments were plotted in the same manner as Fig. 1. Using the vertical axis intercept of these curves as initial enzyme activity (C_O), the normalized curves were established using the Wang Computer. Results of the analysis are summarized in Table 2. The rate constant for enzyme inactivation was highly pH dependent.

Table 2. Rate constants of polygalacturonase inactivation in cherry brine at 69°C and different pH values

pH	Correl.[1] Coeff.	$k \times 10^2$ (s^{-1})	D (s)
2.5	.9988	4.848	47.50
3.0	.9984	3.464	66.54
3.5	.9976	3.812	60.41
4.0	.9990	4.947	46.55

[1] For C/C_0 versus time.

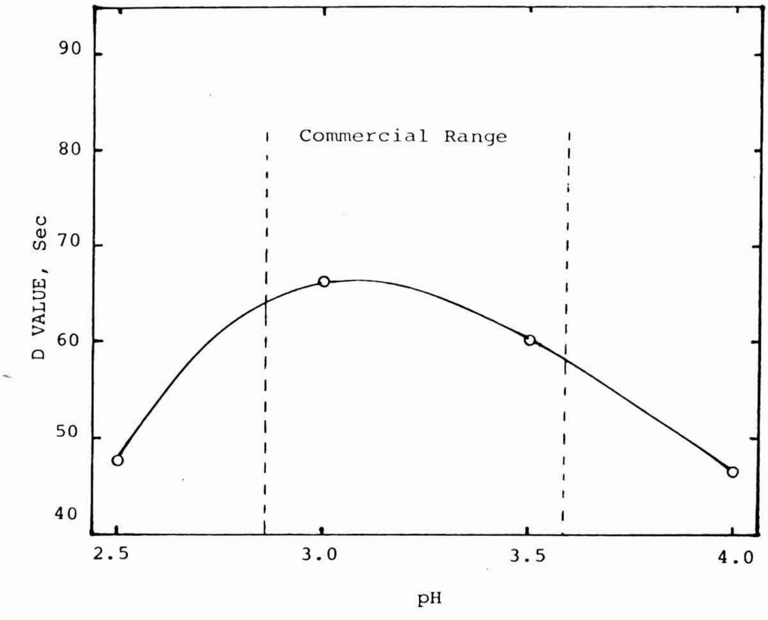

FIG. 4. EFFECT OF pH ON THE DECIMAL REDUCTION TIME AT 69°C

The influence of pH on the decimal reduction time (D) is not linear, as illustrated in Fig. 4. The resistance of the enzyme to inactivation by heat is higher at pH values between 2.8 to 3.5 than at pH values of 2.5 and 4.0. Figure 4 indicates that the enzyme exhibits more stability at pH values usually employed for commercial brines.

The influence of pH on inactivation of polygalacturonase in cherry brine is similar to results for other enzymes. Farkas and Goldblith (1962) reported that the inactivation rate of the enzyme lipoxidase is faster at pH values of 4.0 and 9.0 than at pH values between 4 and 7. The stability to inactivation by heat of 1.0 mg/ml solutions of purified spinach catalase was higher at pH values of 5.0 or 7.0 than at pH 9.0 at 55°C (Sapers and Nickerson 1962).

C. Influence of Sugar Concentration

The pH of commercial brine from Napoleon cherries was adjusted to 3.0 by using a small amount of sodium hydroxide. The sugar content of the brine was measured by an ABBE refractometer and a value of 9% was determined. High fructose corn syrup was used to adjust the sugar concentration in two samples to 12 and 14%, respectively. The enzyme inactivation rates were measured at three sugar levels; 9, 12 and 14%.

The results of the experiments are summarized in Table 3. The rate constants (k) were determined from experimental data using the Wang Computer least-squares fitting program and the decimal reduction time (D) was computed from Eq. (3).

Table 3. Rate constants of polygalacturonase inactivation in cherry brine at 69°C and different sugar concentrations

Sugar (%)	Correl.[1] Coeff.	$k \times 10^2$ (s^{-1})	D (s)
9	.998	3.462	67.0
12	.997	3.299	70.0
14	.994	2.574	92.5

[1] For C/C_O versus time.

Values of both k and D are presented in Table 3, as well as the correlation coefficients for C/C_O versus time. The influence of the sugar concentration on the decimal reduction time is illustrated by the curve shown in Fig. 5.

At lower sugar concentrations, the inactivation rate is not significantly influenced by the sugar concentration. As is illustrated by the curve (Fig. 5), the decimal reduction time (D) increases as the sugar concentration is increased above 12%. This influence is significant, as established by the statistical "t" test, and has to be taken into consideration when pasteurization units are designed for brines used for more than one year. Reuse of the brine would result in an increase in concentration of the sugars

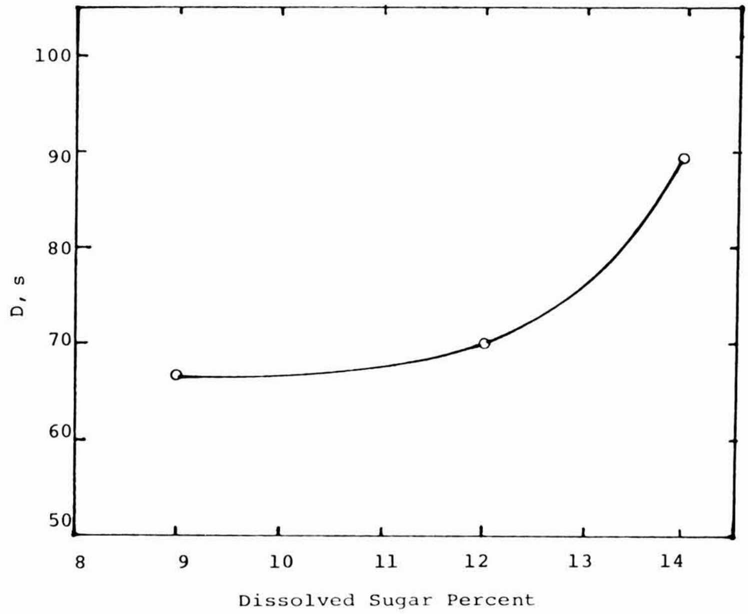

FIG. 5. EFFECT OF DISSOLVED SUGARS ON D VALUE AT 69°C AND pH = 3.0

in such brines each year. Observations based on Fig. 3 and 5 indicate that the pasteurization temperature must be increased by about 1.5°C to overcome the effect of the higher sugar concentration at pH = 3.0.

CONCLUSIONS

The results of this investigation provide information leading to the following conclusions:

(1) The thermal inactivation of polygalacturonase enzyme in cherry brine can be described by equations based on first-order kinetics.
(2) Magnitudes of activations energies describing the influence of temperature on inactivation rates are within the range normally expected for thermal inactivation of enzymes.
(3) Polygalacturonase enzyme in cherry brine tends to be most thermally stable in a pH range typical for commercial brines.
(4) Increased concentrations of sugar, as would occur during reuse of cherry brine, will increase the thermal stability of polygalacturonase.

ACKNOWLEDGMENT

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LITERATURE ABSTRACTS

ABSTRACTS FROM THE JOURNAL OF FOOD SCIENCE

Each of the following abstracts has been reprinted with permission from the *Journal of Food Science.*

COMPUTER SIMULATION OF PARTIAL SPOILAGE DATA. J. Hachigian. J. Food Sci. *43*, 1741—1748.

Partial spoilage data are generated by simulating experimental methods frequently used in food science. The basic experimental model that is simulated is as follows: N tubes (or cans) of substrate (food) are inoculated with a microbiological contaminant (e.g. PA 3679 or *C. Botulinum*). These replicates are then subjected to a lethal environment (heat or radiation, etc.) and after incubation the replicates are tested to determine the number of replicates with viable contaminants remaining. Exact counts are not possible. The algorithm developed has many useful options, so that the simulation can be used within many areas of food science. The basis of the methodology is probabilistic, and food scientists may use it to generate replicate data necessary for statistical analyses. The technique can be useful for understanding the underlying microbiological phenomena. Repetitive runs may be used for comparative analysis with actual experimental results, in an inexpensive way. The methodology also provides a possible explanation of "skips" and "tailing" as has been observed in partial spoilage data.

DIFFERENTIAL SCANNING CALORIMETRY OF NONFREEZABLE WATER IN SOLUTE-MACROMOLECULE-WATER SYSTEMS. K. D. Ross. J. Food Sci. *43*, 1812—1815.

Differential scanning calorimetry was employed to determine the amount of bound (nonfreezable) water in several model systems as a function of water activity (a_w). Water activity was controlled by varying total moisture content or by adding a solute, urea, to the aqueous phase of the model system. Since the amount of bound water is dependent on the nature of the components, correlations between bound water and a_w are meaningful only for specific systems. In every case studied, bound water, as g H_2O/g solids, decreased with decreasing a_w, along what might be called a bound water isotherm. The results indicate that measurements of bound water should refer to a specified value of a_w. In addition, a_w of the solution phase appears to be a major contributor to the driving force for water binding by macromolecules.

FLOW CHARACTERISTICS OF NON-NEWTONIAN FOODS UTILIZING A LOW-COST ROTATIONAL VISCOMETER. D. L. Griffith and V. N. M. Rao. J. Food Sci. *43*, 1876—1877.

Various cups and bobs were constructed for use with a Brookfield Rheolog viscometer. The bobs were examined for end effects utilizing standard solutions of known viscosity and corrected bob heights determined. Improved rotational capabilities were provided by combining an audio generator, amplifier and power transformer to give decreased, intermediate and increased speeds of rotation. This system proved accurate when tested with a Newtonian product (sucrose solutions) and gave flow constants not significantly different from those obtained using a Haake Rotovisco for the evaluation of a non-Newtonian product (orange juice).

DEVELOPMENT AND STORAGE STABILITY OF INTERMEDIATE MOISTURE CARROT. K. S. Jayaraman and D. K. Dasgupta. J. Food Sci. *43*, 1880—1881.

Intermediate moisture carrot slices were prepared by soaking the blanched slices for 12-16 hr in 6% brine followed by partial hot air dehydration to 50% moisture. Sucrose and glycerol at 10% and 5% levels respectively in the soak solution improved their texture on rehydration significantly. The concentrations of additives used were sufficient to ensure microbiological stability at the IM level but reached tolerable levels to taste on rehydration. Coating of the slices with BHA combined with mild compression yielded a shelf life of more than 6 months at room temperature and 37°C as judged by carotene loss and off-flavor development.

ACCELERATED METHOD FOR DETERMINING THE KINETIC MODEL OF ASCORBIC ACID LOSS DURING DEHYDRATION. L. Saguy, S. Mizrahi, R. Villota and M. Karel. J. Food Sci. *43*, 1861—1864.

An accelerated method for determining the kinetic model which describes the loss of ascorbic acid during air drying was developed. The method is based on tests conducted under dynamic conditions, i.e. ascorbic acid loss is studied in the course of the dehydration process during which temperature and moisture content are changing continuously. The results are used to determine the form of the kinetic model and the kinetic parameters relating rate of loss to moisture content, temperature, and reactant concentration. The method successfully predicted the kinetic model describing the loss of ascorbic acid in a simulated air drying process. This approach may eliminate the necessity for time-consuming experiments conducted at each of several combinations of temperature and moisture content and may be applicable to other deteriorative reactions.

KINETICS OF WATER VAPOR DESORPTION FROM APPLES. G. M. Roman, E. Rotstein and M. J. Urbicain. J. Food Sci. *44*, 193—197.

Water is desorbed from apples in two stages. The initial stage is characterized by a very fast release of water. The second stage corresponds to low moisture contents and a low rate of desorption. The process can be mathematically modeled in different ways depending on whether or not the true tissue structure is taken into account. These alternative ways are reviewed, compared and used to analyze the mechanisms involved.

THERMAL CONDUCTIVITY OF APPLES AS A FUNCTION OF MOISTURE CONTENT. J. E. Lozano, M. J. Urbicain and E. Rotstein. J. Food Sci. *44*, 198—199.

The thermal conductivity of apples over the entire range of moisture contents, from bone-dry to full turgor, was measured by means of a thermal conductivity probe. Data are reported, correlated, compared with the scarce information available and discussed from the standpoint of the fruit constituents.

A HEAT TRANSFER CORRELATION FOR ROTARY STEAM-COIL VACUUM EVAPORATION OF TOMATO PASTE. C. S. Chen, V. M. Lima Hon and A. Marsaioli Jr. J. Food Sci. *44*, 200—203.

The rate of heat transfer is required in designing and sizing the heat transfer surface necessary for heat exchangers. A heat transfer correlation equation was determined for a rotary steam-coil vacuum evaporator for concentrating tomato juice at the temperature difference of 120-130°F. A Nusselt-type dimensionless equation was obtained as follows: $h_oD_t/k = 0.60\ X_s^{-2.51}\ (\rho ND_c^2/\mu)^{0.62}\ (c_p\mu/k)^{1/3}\ (\mu/\mu_w)^{0.14}$ in which h_o is the film coefficient for the product side of coil surface; D_c is the outside diameter of rotary coil; D_t is the inside diameter of the mixing vessel; k is the thermal conductivity; X_s is the solids content in decimal; ρ is the density; N is the speed of the rotary coil; μ is the viscosity; and c_p is the specific heat. All fluid properties were evaluated at the arithmetic mean temperature of the bulk fluid and the wall except the μ_w which was evaluated at the wall temperature. The Reynolds number is in the range of 1—200 and solids content 20-50%.

ALTERNATE PROCESSES FOR USE IN SOY PROTEIN ISOLATION BY INDUSTRIAL ULTRAFILTRATION MEMBRANES. J. T. Lawhon, D. W. Hensley, M. Mizukoski and D. Mulsow. J. Food Sci. *44*, 213—215.

Two alternative procedures have been developed for use in soy protein isolation with industrial membrane systems. These are (1) membrane processing soy extract at a higher pH (pH 11) and temperature (74°C) than previously done to produce a hydrolyzed product, (2) extracting soy protein with $Ca(OH)_2$ (instead of NaOH) and membrane processing at pH 7. Hydrolyzed products were found to possess different physical and functional properties than previous products. Extracting soy protein with $Ca(OH)_2$ produced a high-calcium, low-sodium product having unusually high nitrogen solubility over a wide pH range.

HEATING OF CANNED FOOD IN FLUIDIZED SILICA SAND. J. F. Steffe and R. P. Singh. J. Food Sci. *44*, 237—240.

The primary objective of this study was to determine the convective heat transfer coefficient which could be expected in a fluidized bed retort when the heating medium was air fluidized silica sand. An average heat transfer coefficient of approximately 329 $W/(m^2 C)$ was experimentally determined. Curves for heating conduction and convection type foods in a fluidized bed and a rotary steam retort are compared.

APPLICATION OF A CONTINUOUS CENTRIFUGAL FLUIDIZED BED DRIER TO THE PREPARATION OF QUICK-COOKING RICE PRODUCTS. R. L. Roberts, R. A. Carlson and D. F. Farkas. J. Food Sci. *44*, 248—250.

Parameters developed previously for preparing several quick-cooking rice varieties using a small batch centrifugal fluidized bed drier ("CFB") were adapted to a continuous unit which was operated at rates of 20-60 lb/hr of dried instant type rice products. Minor equipment modifications were made to handle the slightly sticky cooked rice being fed into the continuous drier. High heat transfer rates were obtained with an air flow of 3000 fpm at 132° across the 10-inch diam × 100-inch long drier cylinder rotating at 270 rpm to give a centrifugal force of about 10 times gravity. A 5-min drying time was possible. The process was applied satisfactorily to long-, medium- and short-grain rice varieties. Bulk densities and rehydration characteristics were controlled to meet prescribed recipe directions for consumer use. The CFB process should reduce water usage and energy consumption by minimizing treatment times. Total product cost should be favorable for consumer markets.

CHARACTERIZATION OF THE STRESS RELAXATION CURVES OF SOLID FOODS. M. Peleg. J. Food Sci. *44*, 277—281.

Relaxation curves of Agar gel, apple, bologna sausage, bread, cheddar cheese, pear and potato specimens, at various deformation levels, were normalized and fitted to the equation: $[F_o - F(t)] / F_o = abt/(1 + bt)$ where F_o is the initial force, f(t) the force after time t and a and b constants. Unlike other equations (e.g. a series of exponential terms derived from a Maxwellian model), this equation contains only two constants and these are directly related to the curve shape features. This enables simple comparison between the shape characteristics of curves of different materials. Similarly, the equation facilitates quantitative evaluation of the effects of the straining history on the shape of the stress relaxation curves of solid foods.

AMENDMENTS TO BALL'S FORMULA METHOD FOR CALCULATING THE LETHAL VALUE OF THERMAL PROCESSES. R. J. Steele and P. W. Board. J. Food Sci. *44*, 292–293.

Attention was recently drawn to ambiguities in the derivation and the accuracy of parts of Ball's Formula Method for calculating the lethal value of heat sterilizing processes for canned foods. Unfortunately the suggested corrections to Ball's method are themselves erroneous. This note was prepared to resolve the present confusion and to point out that in practice the Formula Method sometimes underestimates F_c and therefore introduces additional safety factors into some calculated processes.

KINETICS OF AVAILABLE LYSINE LOSSES IN A SOY PROTEIN ISOLATE: CONFIRMATION OF THE "TRANSITION PHASE" BY PROTEIN EFFICIENCY RATIO TESTS. J. C. Wolf, D. R. Thompson, P. C. Ahn and P. V. J. Hegarty. J. Food Sci. *44*, 294—295.

Available lysine losses in soy protein isolates during thermal processing go through three phases: a first-order loss, a transition phase and a no-loss phase. The transition phase shows a statistically significant ($P < 0.02$) increase in available lysine when measured by the fluorodinitrobenzene (FDNB) method. Using the protein efficiency ratio method (PER), a statistically significant ($P < 0.1$) increase in available lysine was demonstrated in samples processed at 80°C for 700 min. The PER values decreased from 2.65 ± 0.04 to 1.17 ± 0.04 after 600 min of processing. At 700 min the PER value increased to 1.37 ± 0.05. At 80°C the transition phase in systems containing 4% sugar occurs 600 min after processing is initiated according to previously published equations. The PER and FDNB results exhibited an excellent correlation (r = 0.98). Thus, PER results confirm the increase detected using the FDNB procedure.

INFLUENCE OF PRESSURIZATION ON BINDING STRENGTH OF TURKEY MEAT ROLLS STUFFED IN MEMBRANE CASINGS. S. Meydav, R. T. Toledo and J. A. Carpenter. J. Food Sci. *44*, 298—299.

The influence of pressurization on binding strength between meat pieces stuffed into membrane casings was evaluated using a pneumatic pressurization device. This device simulated the action of a pneumatic machine that is commercially available and is now used by the industry. The contents of a stuffed casing were pressurized when the open end was twisted and inserted through a 1 cm diameter opening on a fixed aluminum ring and pulled by an air cylinder piston to which the casing was attached. Using theoretical considerations, an equation was derived for determining internal pressure in a stuffed roll based on the principle that the pressure developed is a function of the unit strain on the casing. This principle was verified experimentally by monitoring internal pressures in a casing filled with a viscous fluid and connected to a mercury manometer. The internal pressure was linear in a plot against the reciprocal of the outside diameter of the roll. The regression equation was used to calculate internal pressures in a casing stuffed with meat from the measured outside diameter. Interfacial binding evaluated as failure force in uniaxial tension decreased slightly with increasing pressures in the roll in excess of 5.7 psig. The decrease was insignificant in rolls made from frozen meat but was significant in rolls made from fresh meat. In unpressurized rolls, increased incidence of pockets filled with cookout fluid was observed. Pressurization to 2-5 psig internal pressure appears to be optimal in terms of elimination of pockets filled with cookout fluid and maximum interfacial binding between meat pieces.

NONSYMMETRIC HEAT CONDUCTION IN AN INFINITE SLAB. J. Uno and K. Hayakawa. J. Food Sci. *44*, 396—403.

The geometrical configuration of many food products may be approximated with an infinite slab, in so far as their heat transfer characteristics are concerned. Several researchers have utilized formulae for predicting transient state heat conduction in an infinite slab undergoing symmetric heat exchange with surrounding medium. However, in a number of food manufacturing processes, the heat transfer rate through one surface of the slab is not identical to that through another surface. There is a published analytical formula available for estimating transient state heat conduction in an infinite slab subjected to nonsymmetric heat exchange with surrounding medium. However, it is impractical because of mathematical difficulty, to apply directly this analytical formula for estimating the temperature of food subjected to nonsymmetric heating or cooling processes. Therefore, computer programs were developed to simplify this application. The programs are for the estimation of characteristic roots, transient state temperature, f and j values and the location of the thermal center. From computational results obtained by using these programs, we then developed a set of charts to simplify the estimation of food temperatures. Examples for the use of the method are included in this presentation.

A SPECIFIC HEAT CALORIMETER FOR FOODS. M. P. Hwang and K. Hayakawa. J. Food Sci. *44*, 435—438.

A new procedure was developed to determine the specific heat of food products by using a calorimeter which was prepared through the proper modification of a household vacuum jar. Since there was no direct contact between food and heat exchange medium in the calorimeter, the evaluation of heat of solution for dissolvable chemical entities in the food was eliminated and also this new method is readily applicable to food whose temperature is higher than 100°C. The reproducibility and reliability of the developed procedure were carefully examined by using several materials whose specific heat values were well documented. This procedure was utilized to determine specific heat values of four cookies, wheat flour and one fresh produce. The agreement between the experimental and literature values was found to be excellent. The standard deviations of replicated experiments were less than 2%.

A NEW METHOD FOR DETERMINING THE APPARENT THERMAL DIFFUSIVITY OF THERMALLY CONDUCTIVE FOOD. S. R. Bhowmik and K. Hayakawa. J. Food Sci. *44*, 469—474.

Two empirical parameters, j and f, have been used to determine the thermal diffusivity values of food by several researchers. Since there are considerable variations in j values, a new procedure was developed for the experimental determination of thermal diffusivity of foods without using this parametric value. A sample was filled into a cylindrical cell whose diameter and length were approximately 10 and 130 mm, respectively. The temperatures of the sample were monitored at the mid-point of the central axis and on the inside surface of the cell. These temperatures were used to estimate thermal diffusivity values together with an analytical formula for heat conduction in an infinite cylinder. The method was utilized to determine the thermal diffusivity, Biot number, and surface heat conductance values of water, 60% sucrose solution, glycerine, cherry tomato pulp, and apple pulp. There was close agreement between thermal diffusivity values determined experimentally and such values available in published literature. Mathematical procedures are presented for estimating errors in the thermophysical property values determined experimentally, where there are errors in locating temperature sensors in a sample, errors in the shape of the diffusivity cell, and errors in the temperature sensing device.

VISCOMETRIC CHARACTERISTICS OF WHOLE SOYBEAN MILK. L. L. Forster and L. K. Ferrier. J. Food Sci. *44*, 583—585.

The rheological behavior of unflavored, whole soybean milk was evaluated. The standard University of Illinois beverage was adequately described by the general power law equation. The soy milk displayed pseudoplastic flow behavior and was mildly thixotropic. The consistency coefficient of the soy beverage decreased with increasing temperature but the flow behavior index was unaltered at higher temperatures. At higher solids levels the apparent viscosity and degree of pseudoplasticity of the beverage increased. Inclusion of soybean hulls in the beverage caused higher apparent viscosity than observed in beverages made from dehulled cotyledons. The doubly homogenized beverage had lower apparent viscosity and greater adherence to Newtonian behavior than the singly homogenized beverage. Beverages prepared from cotyledons blanched in 0.25% $NaHCO_3$ had higher apparent viscosities and were more pseudoplastic than beverages prepared from cotyledons blanched in an acid solution or in tap water.

HEATING CHARACTERISTICS OF CREAM-STYLE CORN PROCESSED IN A STERITORT: EFFECTS OF HEADSPACE, REEL SPEED, AND CONSISTENCY. M. R. Berry, Jr., R. A. Savage and I. J. Pflug. J. Food Sci. *44*, 831–835.

The heat penetration factors (f_h and j) and sterilization value (F_o) for cans of cream-style corn heated in an FMC Steritort were determined from time-temperature data as a function of container headspace, reel speed, and product consistency. Four commercially prepared cream-style corn in 303 × 406 cans, headspace (or fill weight) is the most critical of these parameters. Sterilization values that ranged from 39 to 78 min for 1/4 in. gross headspace were reduced to less than 1 min when the headspace bubble was eliminated. Positive headspacing devices or net-weight sensors are recommended for control of product lines. Other parameters that significantly influence the degree of agitation induced within the can are rotational speed of the cooker and product consistency. At low reel speeds or high product consistencies, sterilization values decrease dramatically.

ANALYSIS OF CONTINUOUS STERILIZATION PROCESSES FOR BINGHAM PLASTIC FLUIDS IN LAMINAR FLOW. C. Guariguata, J. A. Barreiro and G. Guariguata. J. Food Sci. *44*, 905–910.

A model was developed to represent the continuous sterilization of Bingham plastic fluid foods for the laminar, isoviscous and nonisoviscous flow, with applications to design. The length of the heating and cooling sections as well as nutrient retention were numerically calculated for a required sterilization value. Thiamine and *C. botulinum* were considered for this purpose. There was a considerable difference between solutions obtained for isoviscous and nonisoviscous flow. Therefore, it would not be advisable to overlook the temperature effect on rheological fluid properties. Optimal nutrient retention was shown to occur for the smallest tube diameter studied.

ABSTRACTS FROM TRANSACTIONS OF THE ASAE

DETECTION AND REMOVAL OF COCKLEBURS IN DELINTED COTTON SEED BY STAINING OF THE LIGNEOUS HULL USING SELECTED AROMATIC AMINE SALTS. D. M. Hall, W. S. Perkins. Trans. ASAE *21* FE, 399–400.

Acid delinting of cotton seed removes the spiny projections from cocklebur seed making subsequent separation of the cockleburs from the cotton seed difficult. Salts of aromatic amines such as para-nitro aniline form colored compounds with the lignin in the cocklebur hull. Coloration of the cockleburs assists in the detection for removal by manual or spectrophotometric machine methods giving cocklebur free seed for planting. Flotation methods relying of density differences between the cocklebur and cotton seed can be employed if use of the aromatic amine is not desirable.

MICROBIAL PROTEIN PRODUCTION FROM WHEY AND CASSAVA. A. G. Meiering, F. A. Azi, K. F. Gregory. Trans. ASAE *21* FE, 586–593.

A simple fermenter based on the Waldhof principle was developed for the production of microbial protein from whey and cassava. A. *K. fragilis* culture was used for the fermentation of whey with an initial lactose concentration of 50 g/L. An *A. fugigatus* mutant I-21A was used to enrich the protein deficient cassava with microbial biomass. The true protein concentration of the cassava was raised to 27%. The fermentation processes were simulated in order to predict the fermenter performance under different conditions in batch as well as continuous flow operation. The nutritional value of the protein enriched cassava was analyzed in feeding tests with rats and showed significant differences from standard feed rations.

MECHANICS OF IMPACT OF A FALLING FRUIT ON A CUSHIONED SURFACE. N. N. Mohsenin, V. K. Jindal, A. N. Manor. Trans. ASAE *21* FE, 594—600.

This paper presents the theoretical aspects of the mechanics of impact of a falling fruit on soft cushioned surfaces. A simple graphical procedure follows the proposed solution for selecting an appropriate cushioning material for a fruit catching platform. Experimental results are provided to verify the theoretical solution for the case of some selected fruits such as apples. For this verification, the mechanical properties of the fruit and the cushioning materials were needed to be determined under both static and impact conditions.

DYNAMIC STIFFNESS OF RICE GRAIN. P. K. Chattopadhyay, D. D. Hamann, J. R. Hammerle. Trans. ASAE *21* FE, 786—789.

Experiments to determine dynamic mechanical properties of brown rice, variety IR-8, were carried out with cylindrically shaped specimens tested uniaxially along the cylindrical axis. Storage and loss moduli were determined from 100 to 1000 Hz forcing frequency at four different moisture levels from 12 to 29% (dry basis). Statistical analyses of the test data revealed the stress-strain relations for the rice grain to be frequency as well as moisture dependent with the moduli increasing with frequency of loading and decreasing with moisture content. Statistical curve fitting resulted in a mathematical relaxation modulus expression at each moisture level that was equivalent to a Maxwell model mechanical representation. General equations for storage and loss moduli as functions of frequency and moisture content were also developed.

FORMULATION OF MODELS FOR CUSHION MATERIALS FOR IMPACT APPLICATIONS. W. J. Kennish, Jr., J. M. Henderson. Trans. ASAE *21* FE, 793—796.

The process of developing a relatively simple computer model to simulate the dynamics of a cushion is described The desired model characteristics are obtained with the combination of two commonly used models for viscoelastic materials. The combination is then reduced to a nonlinear single element Voigt-Kelvin model for the particular application of interest.

TOMATO COLOR MEASUREMENT VERSUS MATURITY. S. Moini, M. O'Brien. Trans. ASAE *21* FE, 797—800.

Light reflectance characteristics of tomatoes are used to evaluate the quality of fruit and provide a means of sorting for tomatoes. Reflectance studies have been undertaken to establish several criteria using combinations of light reflectances at different wavelengths, which will provide good separation of acceptable tomatoes for processing from unacceptable tomatoes, dirt clods, and stones. Reference levels for separation have been established at the 99.5% confidence level.

MATERIALS AND METHODS FOR NOISE REDUCTION IN CANNERY ENVIRONMENTS. S. A. Waggoner, J. F. Shackelford, F. F. Robbins, Jr., T. H. Burkhardt, M. O'Brien. Trans. ASAE *21* FE, 1002—1008, 1014.

General installation techniques for sound absorption materials, vibration damping materials, and barrier materials which can be used in a food processing environment are presented. Various can-wall thicknesses produced no significant effect on sound pressure levels. One mil plastic films should be draped over sound absorption materials for cleanability. A viscoelastic bonding compound sandwiched between sheet metal panels is an economical damping method. Enclosures will generally give the most significant noise reductions on existing machinery. Isolating can lines from the cannery worker and installing nylon covered cables are solutions already implemented. Noise control methods for depalletizers, gravity tracks, and twists are included.

EQUATION FOR THE DYNAMIC COMPLEX UNIAXIAL COMPRESSION MODULUS OF SPHEROIDAL SHAPED FOODS. D. D. Hamann, K. C. Diehl, Jr. Trans. ASAE *21* FE, 1009—1014.

Determination of the axial compression complex modulus of spheroidal shaped foods by sinusoidal direct stress-direct strain is not possible using the Hertz contact theory because the contact surface area is not all caused by the sinusoidal forcing. A static preload is normally used to hold the specimen in place and a sinusoidal forcing superimposed. Inability to use the Hertz equation in this situation is demonstrated experimentally and an alternative equation sought. Using dimensional analysis and test data for 176 specimens involving a variety of fruits and vegetables (88 ellipsoidal specimens and 88 cylindrical specimens) tested at 2 Hz and 144 specimens tested at 80 Hz, the equation $|E^*| = 1.51\ F/(D\ d_c)$ for spheroidal specimens was developed where $|E^*|$ is the absolute value of the complex modulus, F is peak to peak force, D is peak to peak displacement and d_c is the mean contact diameter (including both contact surfaces of an axially compressed spheroid). Any consistent set of units is suitable. Using this developed equation, the R^2 value for the modulus was 0.97.

COMPUTERIZED SIMULATION FOR HEAT TRANSFER AND MOISTURE LOSS FROM AN IDEALIZED FRESH PRODUCE. K. Hayakawa. Trans. ASAE *21* FE, 1015—1024.

A realistic mathematical model is developed to simulate heat transfer and moisture loss from fresh produce subjected to cooling processes. The overall configuration of fresh produce is assumed to be an infinite slab. The model is represented with a nonlinear partial differential equation, which is solved by applying a general implicit finite difference method. The model is utilized to examine the influence of several physical parameters on moisture loss as well as transient state temperature distribution in an idealized fresh produce.

MECHANICALLY ASSISTED GRADING OF ORANGES FOR PROCESSING. W. L. Bryan, B. J. Anderson, J. M. Miller. Trans. ASAE *21* FE, 1226—1231.

A "mechanically-assisted" manual grading process improved effectiveness of removal of unwholesome or "cull" fruit during the unloading of oranges at a processing plant. In this process, most culls were separated mechanically by differences in bouncing behavior into a side stream containing less than 15% of the total fruit flow. Only the small side stream then required manual grading before storing fruit in bins. When this process was used, efficiency of manual grading was almost twice that of conventional procedures because the stream requiring inspection was small and the concentration of culls was 5 to 15 times that in the original fruit. The process was demonstrated on 1/3 commercial scale in a pilot fruit-receiving system at a citrus processing plant.

FOOD DRYING WITH DIRECT SOLAR AUGMENTED BY FOSSIL ENERGY. W. L. Bryan, C. J. Wagner, Jr., R. E. Berry. Trans. ASAE *21* FE, 1232—1236.

A 24-h, two-stage batch solar-drying process was developed for fruits and vegetables. It involved use of an enclosed solar collector/hot-air dryer with transparent covers and planar reflectors mounted above and beneath to increase solar radiation to the food compartment. The process was demonstrated in preliminary drying tests conducted in autumn (42 to 62 deg noon solar elevation, 28 deg N latitude) with diced carrots and sliced parsley. Most of the moisture was evaporated during the solar stage, and drying was completed overnight with a low flow of air heated by fossil energy sources. During the solar stage, drying rates were 30 to 40% greater when both upper and lower reflectors were used, compared with use of the upper reflector alone.

THERMAL PROCESSING TIMES AND THERMODYNAMIC PROPERTIES OF CANNED MEAT ROLLS. J. S. Cohen, E. Wierbicki. Trans. ASAE *21* FE, 1242—1245.

Beef, pork, ham, and chicken rolls were canned and thermally processed. The thermal processing times required to achieve $F = 6.0$ at 240°F (115.6°C) retort temperature in a 404 × 309 can varied from 153 to 176 min and were significantly correlated with fat and moisture content of the meat. Also, estimates of thermal conductivity and specific heat of the meat are presented.

ANALYSIS OF DIRECT ENERGY USAGE IN VEGETABLE CANNERIES. W. Vergara, M. A. Rao, W. K. Jordan. Trans. ASAE *21* FE, 1246—1249.

Direct energy utilization in four vegetable canneries located in Western New York was analyzed. Energy usage and vegetable production were concentrated over a short period of time. All the energy sources were either fossil fuels or derived from them. Usage of each energy source was identified. Due to intervening efficiencies, only 34% of the energy sequestered is used for processing. A mathematical model of direct energy consumed is proposed. The model assumes that total direct energy consumption in a cannery is a function of vegetable production, technological and labor practices, and environmental factors. Data from one plant were used to determine the coefficients of the model.

BOOK REVIEW

Packaging Regulations. Stanley Sacharow, AVI Publishing Co., Westport, Connecticut. 1979. 205 pp. $25.50 U.S. and Canada. $28.00 Other countries

The disciplines comprising food packaging technology and engineering are so influenced by government legislation and regulation that effective function demands a working knowledge of the fundamentals. Stanley Sacharow's "Packaging Regulations" is the first full-length volume for the lay technical person that deals with the issues.

A terse, almost sketchy book, "Packaging Regulations" hints at the magnitude and complexity of the subject matter, and simultaneously overwhelms the unknowing reader.

A prolific writer on the subjects of packaging, Mr. Sacharow is both knowledgeable and perceptive. His prose is always clear and simple, his style interesting for the student. He recognizes a marketable topic and treats it kindly, transporting the reader from the historical beginnings to a recent yesterday. If a history of twentieth century packaging is ever written (and who better to pen it than scribe Sacharow?) then Stanley Sacharow must be designated its herald.

But depth has never been one of Sacharow's fortés. However valuable as texts, a Sacharow-authored book is a sketch, brushing on the subject matter and quickly moving along so as never to immerse the reader. We are drawn and tantalized — and we might even reread for thought — but rarely for substance or fact.

Issues of packaging regulation and its parent, legislation, have been with us since each of us was drawn into packaging. In their early manifestations, government and food packaging were youthful siblings, related but rivals, and so, tolerant of each other. Since the mid 1960's, however, government has grown up and received its law degree — and packaging has become big business (even if it is a mom and pop operation). Trivial sibling rivalry has blossomed into adversarial epics. Rhetoric fills the legislative halls, official journals, news media, and law offices. Packaging legislation and regulation and their interpretation have become big business. Virtually every action means expensive upheaval.

Packaging subjects entitled as vinyl chloride monomer, polyacrylonitrile, Oregon, Michigan, Minnesota, the retortable pouch and hydrogen peroxide have enormous meaning to the direct participants in these dramas — and represent great costs borne by packagers, their suppliers and eventually their customers. Despite their overall impact and significance, each trigger word connotes comprehension primarily to the direct participants. A party involved in the Michigan beverage package deposit law, for example, probably has no notion of the existence of a raging controversy over acrylonitrile monomer. It is as if, by ignoring an issue that does not affect us immediately, it will pass and never disturb us.

The technical people engaged in packaging were infrequently touched by legislative and regulatory issues until the 1960's. Since then, however, they can hardly move without hitting against a legislative or regulatory boundary. The direction of packaging development is almost dictated from the laws and regulations of this nation.

Yet, until now, no definitive contemporary overview of the situation has been compiled. To have produced a first effort that wholly addressed the subject in understandable language would have been an extraordinary accomplishment. "Packaging Regulations" is a thin sketch that whispers of the substance and complexity.

Mr. Sacharow's paucity of legal training is no hindrance to focussing on the issues. But, the reader is equally unlikely to be from the legal profession.

"Packaging Regulations" is a tautly edited compilation of writings on the general subject. Where emphasis and importance should be stressed, it tends to treat equally topics demanding differing stresses such as indirect food additives and Canadian regulations. Areas having great immediate and potential impact on the packager or his supplier should receive treatment commensurate with their significance. The omission of references and explanation of bottle bills, restrictive legislation or deposit laws is a serious oversight.

Although referenced sufficiently for the serious student to be able to locate relevant information, the use of extensive direct legal quotations rather than explanatory material leaves the reader wondering if further study would clarify or obfuscate. One intent of a book of this nature is to provide the reader with meaningful explanations of complex concepts. Quotes from the regulations might be acceptable to members of the legal profession, but are of little benefit to the more logical mind of the packaging professional.

The reader might well muse the notion of being able to compress the entire geneaology and mass of contemporary packaging regulation into a single thin 205 page volume. It should be evident that many key subjects are discussed in only the briefest of mentions.

Packaging regulation is hardly a casual matter to which the packaging professional is "exposed". While total immersion is the province of the regulators and the legal profession, the issues are far too important to be solely in the hands of lawyers and government officials. The technological, business and financial effects of packaging legislation and regulation are too great to permit the issues to be debated on non-substantive grounds.

Packaging professionals have a responsibility to comprehend the priorities and significances, and to provide relevant inputs and analyses.

Understanding cannot in truth arise from a study of the legal arguments or the media syntax. Certainly, no packaging professional has the resources to dig deeply into the official legal records which often amount to volumes.

Sacharow's "Packaging Regulations" is a noble first attempt to rationalizing the complexity and provide a tool for the packaging technologist. If the book falls short of the mark, is it because of the author's approach or is it because the subject matter demands a discipline that is beyond a mere mortal writer?

For those who are puzzled by the massive verbiage on packaging regulation and who wish a chart, "Packaging Regulations" is a frightening revelation. For the novice student needing initial exposure to principles, "Packaging Regulations" serves a purpose, provided it is supplemented by the wisdom of an experienced teacher.

As a working text for the packaging professional, however, "Packaging Regulations" is less than adequate. The subject cries for a definitive work, updated annually or biannually. It would be a labor of patience and dedication, unread, but frequently referenced.

Readers who fall into the categories of persons likely to benefit from "Packaging Regulations" are commended to it. Others are advised to wait for Sacharow's next book, which is likely to be readable, interesting and even entertaining.

ARRON BRODY

F N P

JOURNALS AND BOOKS IN FOOD SCIENCE AND NUTRITION

JOURNAL OF FOOD SERVICE SYSTEMS — G. E. Livingston and C. M. Chang

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

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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.

HASSON, E. P. and LATIES, G. G. 1976. Separation and characterization of potato lipid acylhydrolases. Plant Physiol. *57*, 142–147.

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.

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Acknowledgments: Acknowledgments should be listed on a separate page.

Short notes will be published where the information is deemed sufficiently important to warrant rapid publication. The format for short papers may be similar to that for regular papers but more concisely written. Short notes may be of a less general nature and written principally for specialists in the particular area with which the manuscript is dealing. Manuscripts which do not meet the requirement of importance and necessity for rapid publication will, after notification of the author(s), be treated as regular papers. Regular papers may be very short.

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