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EDITORIAL

As we start Volume 12 of the Journal of Food Processing and Preservation we invite authors to submit original research manuscripts for publication. We would like to see an increase in the number of papers for the two special sections: (1) Computer Codes and Their Applications and (2) Data Bank.

All papers submitted to the journal should be sent to me at my new address:

Dr. Daryl Lund
Editor, Journal of Food Processing and Preservation
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ADJUSTMENT OF SURFACE CONCENTRATION OF REDUCING SUGARS BEFORE FRYING OF POTATO STRIPS

A. N. CALIFANO[1] and A. CALVELO

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ABSTRACT

A model of heat and mass transfer with simultaneous chemical reaction is proposed for simulating changes in profiles and surface concentration of reducing sugars during warm water blanching and the subsequent holding of potato strips in a hot-dry air stream before frying. This content is partially responsible for the color of the finished product. The proposed model allows the prediction of the best leaching conditions (temperature and time) in terms of the initial sugar content of the tubers, the maximum holding time before frying, and the desired maximum surface concentration of sugars.

INTRODUCTION

The color of frozen French fries is an important quality factor which is influenced by the processing variables and the raw material characteristics (Smith and Davis 1977). Thus, the quality of the finished product is dependent on the conditions used for blanching and frying.

It is widely accepted that sugar concentration, especially reducing sugars, modify the final coloration in French fries, due to a Maillard reaction. The reducing sugar content of potatoes is naturally low, between 100-150 mg/100 g potato (mg%),

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depending on the variety involved. But, when tubers are stored at temperatures below 7 °C a substantial increase in the reducing sugars takes place, reaching values as high as 800 mg% (Marquez and Anon 1986). Therefore, tubers reducing sugar content must be lowered either by reconditioning prior to frying by holding at 20 °C for several weeks or by leaching during water blanching. The first alternative risks the possibilities of sprouting and dehydration. The second one consists of placing the potato strips on conveyor belts that carry them through a hot water bath (warm water blanching). The usual range of water temperature is from 60-80 °C and residence times vary between 5-20 min (Weaver *et al.* 1975; Duckworth 1979). During this warm water blanching process, sugar concentration at the surface of the product decreases due to leaching, resulting in a lighter and more uniform color after frying.

Another possibility is to use two blanchers in series. The first blancher to decrease the sugar content, while the second one, containing a dilute sugar solution, may be used as an aid in adjusting the surface sugar concentration to a desired level (Tressler and Evers 1957; Smith 1975). The blanching operation has other advantages, e.g., improved texture of the final product and reduction of oil adsorption (Smith Davis 1977).

In a previous work, Califano and Calvelo (1983) studied the leaching of reducing sugars from potato spheres to a warm water bath, and they found evidence that besides mass transfer to the bath there exists an internal generation of reducing sugars, probably due to an enzymatic hydrolysis of starch. They proposed a mathematical model for heat and mass transfer with simultaneous chemical reaction to simulate the blanching operation of potato spheres at moderate temperatures and evaluated the diffusion coefficient of reducing sugars in potato. The kinetic constants of reducing sugar generation (pre-exponential factor and activation energy) were also obtained. Results also show that heating of the sphere was very fast and transient heat transfer does not affect the mass transfer behavior.

After warm water blanching the process continues with the strips passing through dry-hot air in order to remove superficial moisture (Weaver *et al* 1975) before they are introduced into the frier. The treatment with hot air reduces the load on the frier and minimizes the rate of hydrolytic breakdown of the fat.

A holding time exists after blanching and before frying due to the time necessary for the superficial drying or as a result of process discontinuities. During this time, reducing sugar profiles tends to disappear, increasing the surface concentration with the corresponding darkening of color in the fried product. The objective of the present work is to simulate changes in profiles and surface concentration of reducing sugars during blanching and "holding time," and establish the optimum conditions that yields an acceptable color upon frying. For this purpose the mass transfer model checked with spherical geometry (Califano and Calvelo 1983) was adapted to the potato strip geometry. According to previous results and looking for a higher degree of simplicity an isothermal strip at water bath temperature was considered.

The same parameters obtained experimentally for potato spheres were used with the corresponding mass transfer coefficients for the strip geometry.

EQUATIONS

Blanching

By considering a potato parallelepiped (potato strip) with a C_0 initial reducing sugar concentration (expressed as g-moles of glucose per m^3 of potato) immersed into a well stirred water bath with a C_f' concentration (expressed as moles of glucose per m^3 of fluid), the mass transfer equation is:

$$\frac{\partial C}{\partial t} = D_G \left[\frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial y^2} + \frac{\partial^2 C}{\partial z^2} \right] + k' \tag{1}$$

where k' is the overall kinetic constant (g-mole/m^3 of potato) (Califano and Calvelo 1983) and D_G is the apparent diffusion coefficient of reducing sugars in potato (m^2/s), which can be expressed in terms of the molecular diffusivity (D_{AB}) and tortuosity factor (Ω) (Sherwood *et al.* 1975) as:

$$D_G = D_{AB}/\epsilon \tag{2}$$

The tortuosity factor is defined as the ratio of the diffusion path to the nominal distance traversed by the solute (Schwartzberg and Chao 1982).

The corresponding initial and boundary conditions are:

$$t = 0;\ C = C_0;\ \text{in the analyzed domain} \tag{3}$$

$$t > 0;\ x = y = z = 0;\ \frac{\partial C}{\partial x} = \frac{\partial C}{\partial y} = \frac{\partial C}{\partial z} = 0 \tag{4}$$

$$t > 0;\ x = L;\ k_L(C_f - C) = \epsilon D_G \frac{\partial C}{\partial x} \tag{5}$$

$$t > 0;\ y = L;\ k_L(C_f - C) = \epsilon D_G \frac{\partial C}{\partial y} \tag{6}$$

$$t > 0;\ z = H;\ k_L(C_f - C) = \epsilon D_G \frac{\partial C}{\partial z} \tag{7}$$

where L and H are the half-width and half-length of the strip, respectively. Moreover k_L is the mass transfer coefficient at the potato-blanch water interface

and ϵ is the volumetric fraction of liquid in the potato, which transforms the concentration per unit volume of liquid C′ into concentration per unit volume of potato C, according to $C' = C/\epsilon$.

The reaction rate term in Eq. (1) is considered as a zero order reaction with a temperature dependence given by:

$$k' = \zeta A \exp [-E_a/R_g \cdot T] \tag{8}$$

(Califano and Calvelo 1983) where ζ is the potato density (kg/m^3), A is the pre-exponential factor and E_a is the activation energy.

Both the strip and the bath were considered to be at the same temperature, T, throughout the process, under the assumption that the rate of heat transfer is much faster than the rate of mass transfer (Lewis number = 0.001). The predicted surface concentration was not noticeably altered by this assumption.

Holding before Frying

The described blanching model with different boundary conditions was also used to represent the strip behavior at the end of the blanching operation, when it is kept at a temperature T′, previous to frying. This second temperature may be equal or not to the bath temperature, and it is assumed to be reached instantaneously. The new boundary conditions period are:

$$t = 0;\ C_0(x,y,z) \qquad \text{(concentration profile at the end of the blanching process)} \tag{9}$$

$$t > 0;\ \frac{\partial C}{\partial x}\Big)_{x=L} = \frac{\partial C}{\partial y}\Big)_{y=L} = \frac{\partial C}{\partial z}\Big)_{z=H} = 0 \tag{10}$$

Solution Method

Equations (1) to (8) were written in terms of finite differences applying an explicit method for developing the concentration profile for each increment of blanching time (Von Rosemberg 1971).

At the end of the blanching period, the system formed by Eq. (1), (4), (8), (9) and (10) was solved in the same way as described above for considering the strip behavior during holding before frying.

Once the concentration profile was obtained as a function of time by means of an IBM Series I Computer, the average concentration of reducing sugars in a 0.25 mm crust was computed through a Simpson's algorithm.

Parameters Used

The mass transfer coefficient k_L was evaluated from the heat transfer coefficient, h, obtained in a previous paper (Califano and Calvelo 1983) by using the heat and mass transfer analogy (Bird *et al.* 1964). The fluid properties were evaluated at the water bath temperature. Values of k_L ranged from 4.1 to 5.5 $\times 10^{-6}$ m/s depending on the blanching temperature. The tortuosity factor and kinetic constants of Califano and Calvelo (1983) were adopted: $\Omega = 1.23$; A = 33.7 g-mole/s kg potato and Ea = 4.184×10^4 J/g-mole.

The diffusion coefficient was assumed to be dependent on temperature according to the Stokes-Einstein equation: $D_{AB} = K\ T/\mu_w$ (Skelland 1974; Schwartzberg and Chao 1982). In this equation μ is the water viscosity at temperature T and K is a constant which depends on the system. For aqueous glucose solutions K = 1.98×10^{-15} kg m/s^2 K (Califano 1981).

The volumetric fraction of solution in potato tissue was considered to be equal to the water content on a wet basis ($\epsilon = 0.80$).

The average density (ρ) and size of the potato strip was assumed to be 1070 kg/m^3 and 1 × 1 × 5 cm, respectively. The initial concentration of reducing sugars was selected between 400-600 mg%.

RESULTS AND DISCUSSION

The average reducing sugar concentration corresponding to a depth of 0.25 mm was obtained for several spots. The location of these spots are shown in Fig. 1. This depth is about the same as the crust width, and, presumably, responsible for the color of the French fry (Brown and Morales 1970).

The concentration profiles at three locations for a strip blanched for 15 min at 60 C and afterwards held in an air stream at 60 C are also shown in Fig. 1.

An average reducing sugar concentration for the crust of up to 240 mg% was considered capable of producing an acceptable color upon frying (Marquez and Anon 1986).

Spots "A" and "B" on faces show the smallest decrease in reducing sugars content during blanching. This was expected due to the higher mass transfer rate existing on the edges and vertices. Consequently, the behavior of these faces will determine the maximum "holding time" before frying to assure an acceptable color. Figure 1 shows that the strip can be kept outside the water bath, without frying, for only a short time before the concentration exceeds 240 mg% in spot "A" (about 2 min).

Although spot "C" allows for a longer holding time, it must be considered that the higher mass transfer rate at this point also involves a thicker crust and consequently a darker color on frying.

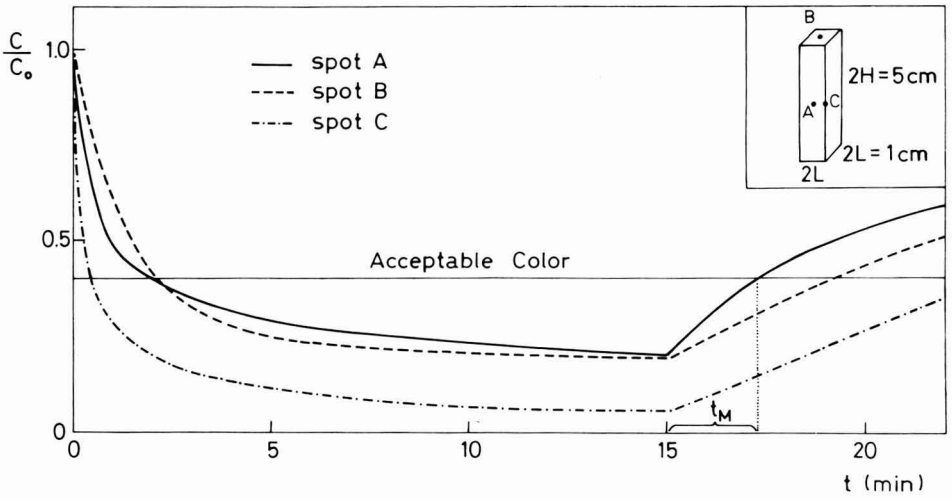

FIG. 1. AVERAGE CONCENTRATION PROFILES AT DIFFERENT SPOTS (DEPTH = 0.25 mm), FOR POTATO STRIPS (C_0 = 600 mg%) BLANCHED FOR 15 MIN AT 60°C, AND AFTERWARD KEPT IN A HOT AIR STREAM AT 60°C. t_M IS THE MAXIMUM TIME THAT STRIPS CAN BE KEPT OUTSIDE THE BLANCHER WITHOUT FRYING.

The blanching of potatoes strips (C_0 = 600 mg%) at temperatures between 60-75°C for different periods, and the subsequent holding outside the frier at the same blanching temperature and at 40°C was also simulated. Table 1 shows the maximum time that the strip can be kept in a hot air stream before the maximum allowed concentration of reducing sugars at spot "A" is reached. This "holding time" increases as expected when the blanching temperatures and/or time increases. It also increases when the air temperature decreases (lower values of k′ and D_G).

The effect of different initial reducing sugars content on the maximum holding times for potato strips blanched at 60°C for 15 min and afterwards held between 60-40°C, are also shown in Table 2. As expected, the lower is the initial sugar concentration the higher is the holding time.

At temperatures higher than 75°C an important enzymatic inactivation probably occurs. In such a case the genration term in Eq. (1) will tend to zero, contributing to increase the holding time. However, the increase of the diffusion coefficient with temperature is by far more important leading to very short holding times. Thus, the blanching of potato strips (C_0 = 600 mg%) at 90°C for 5 min, with holding temperatures of 70° and 90°C, simulated under the assumption of no generation of reduced sugars, showed holding times of less than 1 min.

Some experiments were also conducted to check, at least qualitatively, the predictions of the model. Thus, blanched potato strips were fried after different

TABLE 1
MAXIMUM TIME THAT BLANCHED POTATO STRIPS CAN BE KEPT IN A HOT AIR STREAM BEFORE 240 mg% OF REDUCING SUGARS IS REACHED IN SPOT "A", (C_0 = 600 mg%)

Blanching Temperature (°C)	Blanching Time (min)	Holding Time (min)	
		at blanching temp.	at 40 °C
60	10	2.0	2.1
60	15	2.5	2.9
60	20	3.2	3.6
65	10	2.1	2.4
65	15	2.8	3.1
70	10	2.2	2.6
70	15	2.9	3.2
75	10	2.3	2.8
75	15	3.1	3.3

TABLE 2
MAXIMUM HOLDING TIMES FOR POTATO STRIPS BLANCHED AT 60°C FOR 15 MIN

Air Temperature (°C)	Maximum Holding Time (min)	
	C_o = 500 mg%	C_o = 400 mg%
60	3.9	5.9
50	4.1	6.4
40	4.3	6.9

holding times and colors visually observed. Strong color differences among fried samples were detected with a similar trend to that predicted in computer simulations.

CONCLUSIONS

Difficulties in measuring surface sugar concentration of potato strips after warm water blanching and before frying are overcome by predicting them through a mathematical model. Thus, the model allows to connect a previously obtained relationship between reducing sugar surface concentration and color (Marquez and Anon 1986) with blanching operating conditions and holding times before frying. This assures an acceptable color in the final product.

NOMENCLATURE

A = pre-exponential factor (g-mole/s kg potato)
C = reducing sugar concentration in the potato (g-mole/m^3 potato)
C' = reducing sugar concentration in the potato (g-mole/m^3 fluid)
C_0 = initial concentration (g-mole/m^3 potato)
C_f = fluid concentration (g-mole/m^3 potato)
C_f' = fluid concentration (g-mole/m^3 fluid)
D_{AB} = molecular diffusion coefficient (m^2/s)
D_G = apparent diffusion coefficient of reducing sugars in potato (m^2/s)
E_a = activation energy (J/g-mole)
h = heat transfer coefficient (W/m K)
H = half-length of the potato strip
k' = apparent overall kinetic constant (g-mole/m^3 potato)
k_L = mass transfer coefficient based on concentration (m/s)
K = constant, defined as $K = \mu_w D_G/T$ (kg m/s^2 K)
L = half-width of the potato strip
R_g = ideal gas constant (J/K g-mole)
t = time (s)
T = temperature (K)
x,y,z = orthogonal coordinates (m)

Greek Letters

ϵ = volumetric fraction of liquid in potato
Ω = tortuosity factor
μ_w = water viscosity (kg/m s)
ρ = density (kg/m^3)

REFERENCES

BIRD, R. B., STEWART, W. E. and LIGHTFOOT, E. N. 1976. *Fenomenos de Transporte*, pp. 21-17, Reverte, ed Bs.As., Argentina.

CALIFANO, A. N. 1981. Transferencia de calor y materia durante el escaldado de papas, Ph.D. thesis. Univ. Nac. La Plata, Argentina.

CALIFANO, A. N. and CALVELO, A. 1983. Heat and mass transfer during the warm water blanching of potatoes. J. Food Sci. *48*, 220-225.

DUCKWORTH, R. B. 1979. *Fruit and Vegetables*, pp. 218-222. Pergamon Press, Oxford, U.K.

MARQUEZ, G. and ANON, M. C. 1986. Influence of reducing sugars and amino acids in the color development of fried potatoes. J. Food Sci. *51*, 157-160.

SCHWARTZBERG, H. G. and CHAO, R. Y. 1982. Solute diffusivities in leaching processes. Food Technol. *36*, 73-86.

SHERWOOD, T. K., PIGFORD, R. L. and WILKE, C. R. 1975. *Mass Transfer*, pp. 40, McGraw Hill, Tokyo, Japan.

SKELLAND, A. H. P. 1974. *Diffusional Mass Transfer*, pp. 55, John Wiley & Sons, New York.

SMITH, O. 1975. Potato Chips. In *Potato Processing*, (W. F. Talburt and O. Smith, eds.) pp. 313-321, AVI Publ. Co., Westport, Conn.

SMITH, O. and DAVIS, C. O. 1977. Potato Processing. In *Potatoes: Production, Storage, Processing*, (O. Smith, ed.) pp. 695, AVI Publ. Co., Westport, Conn.

TRESSLER, D. K. and EVERS, C. F. 1957. *The Freezing Preservation of Foods*, Vol. II, pp. 157, AVI Publ. Co., Westport, Conn.

VON ROSEMBERG, D. U. 1971. *Methods for the Numerical Solution of Partial Differential Equations*, Elsevier, New York.

WEAVER, M. L., REEVE, R. M. and KUENEMAN, R. W. 1975. Frozen French Fries and other Potato Products. In *Potato Processing*, (W. F. Talburt and O. Smith, eds.) pp. 418-420, AVI Publ. Co., Westport, Conn.

EFFECT OF pH ON THE HEAT STABILITY OF BOVINE MILK FROM ZEBU AND CROSSBRED CATTLE

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ABSTRACT

The effect of adjusted pH on the heat coagulation time (HCT) of milk from Zebu cattle and their crosses with animals of exotic breeds was determined. It was observed that the majority of individual milks and all the bulk milks from these animals were of Type-A. Further, most of the Type A milks from individual animals and all the samples of bulk milk were most stable at acidic pH or at the natural pH, indicating the unsuitability of common stabilizers during processing. Through selective cross breeding it is possible to produce milk with a desired HCT/pH profile and better stability.

INTRODUCTION

Although the precise mechanism of heat coagulation of milk is not understood yet, pH is the most important single factor which influences the heat stability (Fox 1981). Knowledge of the HCT/pH profile of a milk is helpful in its stabilization by preheating and/or manipulation of pH. For example, Type B milks and those Type A milks in which the pH of maximum stability is located on the alkaline side of the natural pH in the HCT/pH curve are stabilized by an increase in pH with the addition of alkali or salts like disodium phosphate and trisodium citrate (Sweetsur and Muir 1982). Those samples of Type A milk in which the pH of maximum stability is located on the acidic side of natural pH in the HCT/pH curve are stabilized by a decrease in pH with the addition of acid or salts like monosodium phosphate (Sindhu 1985). Still there is a third category of Type A milks which are destabilized by any alteration in pH. These samples are most stable at the natural pH hence any increase or decrease in pH results in their destabilization. Type B milk and Type A milk with a maximum stability on the

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alkaline side of natural pH are stabilized while the Type A milk with a maximum on the acidic side of natural pH is destabilized by preheating (Griffin *et al.* 1976). Studies in different countries have revealed different proportions of Type A and Type B milks (Tessier and Rose 1964; Feagan 1972; Fox 1982). Similarly in Type A milk different proportions of samples with the pH of maximum stability at the natural pH, on the alkaline side of the natural pH and on the acidic side of natural pH have been reported in different countries (Newstead *et al.* 1975; Holt *et al.* 1978; Sweetsur and Muir 1980). However, no work has been done on the HCT/pH profile of milk from Zebu cattle. Consequently, the common type of stabilizers (disodium phosphate and trisodium citrate) and preheat treatment which are used for milk from exotic breed are also being applied to milk from the Zebu cattle without knowing their repercussions. Therefore, the present study was undertaken to determine the effect of adjusted pH on the heat stability of milk from 3 breeds of Zebu cattle so that suitable type of stabilizers and preheat treatment can be selected to achieve the maximum stabilization of milk from these breeds.

The crossbreeding of Zebu cattle with the animals of exotic breeds is being adopted in India and other Asian countries for improving the milk yield. To investigate the effect of such crossbreeding on the HCT/pH profile of milk with a view to explore the possibility for using it for producing more milk of better stability the effect of pH on the heat stability of milk from two cross breeds was also determined.

MATERIALS AND METHODS

Collection of Milk Samples

Milk samples from 42 individual animals of 3 breeds of Zebu cattle (Sahiwal, Tharparkar and Red Sindhi) and 43 samples of two cross breeds, Karan Swiss (Hybrid of Sahiwal and Brown Swiss) and Karan Fries (Hybrid of Tharparkar and Holstein Friesian) maintained at the National Dairy Research Institute Farm were collected. Similarly, bulk milk samples (pooled milk from not less than 20 animals) of each of the above mentioned breeds except Red Sindhi were collected and used for the investigation.

Preheating of Milk

Milk was preheated at 70° ± 1 °C for 20 min. Milk in an Erlenmeyer flask was heated by dipping it in boiling water with constant shaking till the temperature reached 70° ± 1 °C. Thereafter, the samples were transferred to a waterbath at 70° ± 1 °C and held for 20 min. After 20 min the sample was taken out and rapidly cooled to room temperature by circulating cold water over the surface of the flask.

Determination and Adjustment of pH

The pH of milk samples was determined electrometrically with a mains operated digitial pH meter (Elico Model L1-22) using a combination of glass and saturated calomel (referenced) electrode. To study the HCT/pH profile, each sample of milk was divided into 11 lots. The first lot was kept as control and the pH of the remaining 10 lots was adjusted to a pH between 6.3 to 7.2 at 0.1 unit intervals by the addition of either 1-M hydrochloric acid (on the acidic side of natural pH) or 1-M ammonium hydroxide (on the alkaline side of natural pH). After adjustment of the pH to the desired level, the 10 lots of milk were kept for 30 min at room temperature and then the pH of each lot was again determined and readjusted finally to the desired level by the addition of acid or alkali as the case may be.

Determination of Heat Stability

The heat stability of milk was determined as heat coagulation time (HCT) at 130° ± 1°C according to the method of Davies and White (1966) as modified by Jairam *et al.* (1976). Duplicate 1 mL milk samples were placed in corning glass tubes (10 cm in length with 0.8 cm internal diameter and corked at both the ends with silicon rubber corks. The tubes were fitted in an aluminum carriage and heated to 130°C by immersion in the paraffin oil bath. The HCT in minutes was recorded as the time from the moment the tubes were dipped in the oil bath to the first signs of coagulation. The average of each duplicate was taken as the HCT of a sample.

Statistical Analysis

Statistical analysis of the data for F Test was carried on a programmable computer (HCL System-4).

RESULTS

Effect of pH on the HCT of Milk of Individual Animals

The results of the effect of pH on the HCT at 130°C for the milks from individual cows of three Indian breeds (Sahiwal, Red Sindhi and Tharparkar) are presented in Fig. 1 and 2 while results from individual animals of Karkan Swiss and Karan Fries breeds are presented in Fig. 3 and 4, respectively. The average values for the HCT at different pH values from 6.3 to 7.2 are given in Table 1 along with the statistically calculated least significant difference (LSD). In Table 2 are given the HCT values of type A and B milks along with LSD.

HCT/pH Profile of Zebu Cattle. In case of the Sahiwal breeds the majority of the individual milk samples 19 out of 20 (95%) were Type A, i.e. these samples

exhibited a maximum in the HCT at a particular pH (pH 6.5 or 6.6) and minimum at some other pH (at about pH 7.0). The HCT/pH curves for 3 such samples are depicted in graphs A and B in Fig. 1. However, one of the samples was of Type B milks (graph C in Fig. 1) as there was no maximum or minimum in the hCT at any pH; the HCT of this sample increased progressively with increase in pH. Further, some of the samples of Type A milk (20% of the samples) had their pH of maximum stability at the natural pH, i.e. their pH of maximum stability coincided with the natural pH (Graph A in Fig. 1). These samples were destabilized

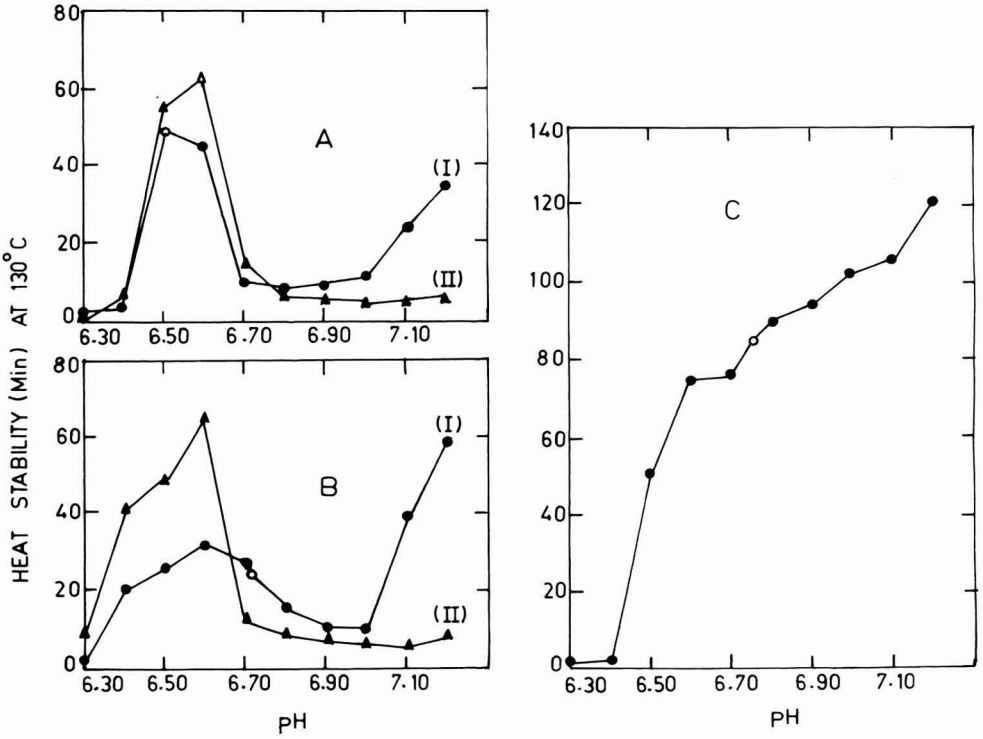

FIG. 1. EFFECT OF pH ON THE HEAT STABILITY OF INDIVIDUAL MILKS FROM SAHIWAL BREED

A — Type A milk with maxima at normal pH.
1) Sharp minima.
2) Extended minima.

B — Type A milk with minima in acidic pH.
1) Sharp minima.
2) Extended minima.

C — Type B milk

Open symbol denotes the unadjusted (natural) pH.

by the addition of acid as well as alkali. The majority of the samples (about 80%) of Type A milk had their pH of maximum stability on the acidic side of natural pH and were stabilized by addition of acid (HCT of one of such sample is depicted as graph B in Fig. 1). The Type A milks from these two categories further differed with respect to a sharp or extended minimum when their pH was increased beyond the pH of minimum HCT. Some of the samples exhibted a sharp increase in the HCT again at about pH 7.0 due to an increase in the pH (Graphs IA and IB in Fig. 1). In some of the samples the HCT remained constantly low (the minimum was extended) when their pH was increased beyond the minimum (Graphs IIA and IIB in Fig. 1).

In the case of milk from individual animals of Tharparkar and Red Sindhi breed of Zebu cattle all the samples analysed (12 and 10, respectively) were of Type A. The HCT/pH curves of the representative samples of Tharparkar breed are depicted in Graphs A in Fig. 2. Six out of the total 12 samples (50%) of Tharparkar breed had their pH of maximum stability on the alkaline side of the natural pH (Graph IA in Fig. 2). These samples were stabilized by the addition of alkali. On the other hand, 50% of the remaining samples of Tharparkar milk had the pH of maximum stability on the acidic side of natural pH (curve for one of such samples is depicted in Graph IIA in Fig. 2). These samples were stabilized by the addition of acid. However, in all the samples of individual milk from the

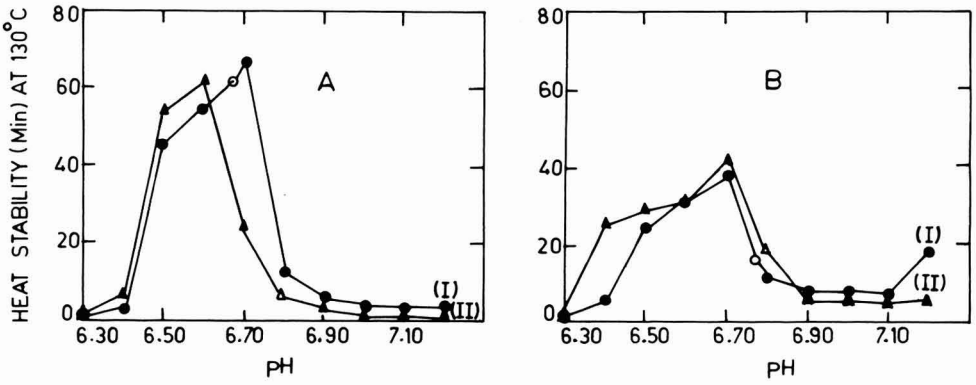

FIG. 2. EFFECT OF pH ON THE HEAT STABILITY OF INDIVIDUAL MILKS FROM THARPARKAR AND RED SINDHI BREEDS

A — Tharparker milk.
1) Type A milk with maxima in alkaline pH.
2) Type A milk with maxima in acidic pH.

B — Red Sindhi milk.
1) Type A milk with maxima in acidic pH and a sharp minima.
2) Type A milk with maxima in acidic pH and an extended minima.

Open symbol denotes the unadjusted (natural) pH.

animals of Tharparkar breed the minimum was found to be extended over the pH range from 6.8 to 7.2. Like Tharparkar milk all the samples from individual animals of Red Sindhi breed were of Type A milk. However, contrary to the Type A milk from Sahiwal and Tharparkar breed all the 10 samples of the Red Sindhi breed had their pH maximum stability consistently on the acidic side (between pH 6.6 to 6.7) of the natural pH, 6.77 (Graph B in Fig. 2). With respect to the behavior of HCT when the pH was increased beyond the pH of the minimum stability, milk from the individual animals of Red Sindhi breed was similar to the Sahiwal milk as some of the samples exhibited a sharp minimum (Graph IB in Fig. 2) while in others it was found to be extended (Graph IIB in Fig. 2).

The statistical analysis of the data (Table 1) established that alteration in pH (between 6.3 to 7.2) had a significant effect on the heat stability of Zebu cattle ($F = 5.78$ for Sahiwal, 12.48 for Tharparkar and 32.30 for Red Sindhi at $P < 0.01$). The least significant difference (LSD) further revealed that Sahiwal and Tharparkar milks were most stable between pH 6.5 to 6.6 and the Red Sindhi milk was most stable between pH 6.6 to 6.7.

HCT/pH Profile of Milk from Cross Bred Cows. All the individual samples of milk from 23 animals of Karan Swiss (a cross between Sahiwal and Brown Swiss) were of Type A milk (with a maximum in HCT at pH 6.5 to 6.6 and minimum at pH 6.9 to 7.0). However, depending on the location of the pH of maximum stability on the HCT/pH curve with respect to natural pH there were three categories of samples (Fig. 3). About 22% of the samples were most stable at a pH which was on the alkaline side of natural pH (Graph A, Fig. 3). The majority of the samples (52%) were most stable at a pH which was located on the acidic side of the natural pH (Graph C, Fig. 3) and were stabilized by the addition of acid: In the third category were those samples (26%) which were most stable at their natural pH (Graph B, Fig. 3) hence addition of acid and alkali both resulted in the destabilization of these samples. The milk samples of the above mentioned 3 categories were further divided into 2 classes depending on the behavior of their HCT when the pH was increased beyond the pH of the minimum. Some of the samples exhibited a sharp minimum at pH 6.9 or 7.0 (Graphs 1A, 1B and 1C in Fig. 3) while in others it was extended upto pH 7.2 (Graphs IIA, IIB and IIC in Fig. 3). In individual milks from 20 Karan Fries (a cross between Tharparkar and Holstein Fresian) only one sample was of Type B milk (Graph D in Fig. 4). Out of the remaining 19 samples (which were of Type A milk) the majority (10 samples) were of Type A milk with a pH of maximum on the alkaline side of normal pH (Graphs A in Fig. 4). Some of these samples had a sharp minimum at about pH 6.8 or 6.9 (Graph IA, Fig. 4) while others exhibited an extended maxima (Graph IIA, Fig. 4). About 25% of the samples had the maximum HCT at normal pH (Graph B in Fig. 4) and the rest (about 20%) had it on the acidic side of natural pH (Fig. 4, Graph C). None of the samples with a maximum on the acidic side had an extended minimum while some of the samples with a maximum at normal pH exhibited this phenomena (Graph IIB in Fig. 4).

TABLE 1

EFFECT OF pH ON THE HEAT-COAGULATION TIME (HCT) AT 130°C OF INDIVIDUAL MILKS FROM ZEBU AND CROSS BREED CATTLE

Sr. No.	Name of Breed	No. of samples	Type of milk											LSD
			Normal		pH adjusted									
			pH	HCT (min)	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	
					HCT (min)										
1.	Sahiwal	20	6.67	30.11	13.02	32.25	50.92	45.66	25.37	20.44	26.91	32.76	45.74	53.38	14.95
2.	Tharparkar	12	6.77	32.75	1.13	5.21	41.66	43.56	39.00	22.32	10.54	4.70	3.12	2.77	4.34
3.	Red Singhi	10	6.77	18.14	1.95	11.30	26.50	30.00	34.10	17.06	8.88	6.75	5.50	8.17	7.21
4.	Karan Swiss	23	6.60	45.39	23.41	45.52	58.77	52.40	30.30	26.05	21.29	24.28	31.42	42.82	14.87
5.	Karan Fries	20	6.65	54.75	9.40	26.80	41.07	54.29	50.86	37.98	26.70	26.90	36.15	44.18	11.35

LSD = Least significant difference at $P < 0.01$.

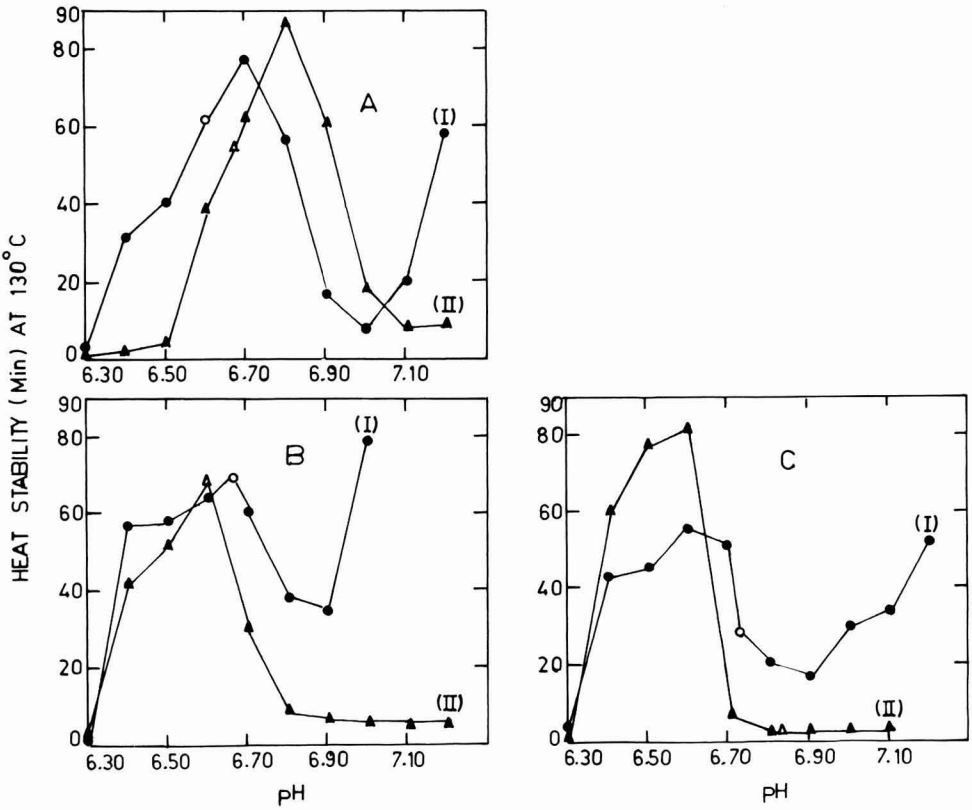

FIG. 3. EFFECT OF pH ON THE HEAT STABILITY OF INDIVIDUAL MILKS FROM KARAN SWISS BREED

A — Type A milk with maxima at alkaline pH.
1) Sharp minima.
2) Extended minima.

B — Type A milk with maxima at normal pH.
1) Sharp minima.
2) Extended minima.

C — Type A milk with maxima at acidic pH.
1) Sharp minima.
2) Extended minima.

Open symbol denotes the unadjusted (natural) pH.

The HCT of cross breed milk was also affected to a significant extent ($F = 5.89$ for Karan Swiss and 11.65 for Karan Fries milks at $P < 0.01$). The Karan Swiss milk was most stable between pH 6.5 to 6.6 (LSD, 14.87 min in greater than the difference, 6.32 min between the HCT values at pH 6.5 and 6.6). The Karan Fries milk was most stable between pH 6.6 to 6.7 (LSD, 11.35 min greater than the difference between HCT values at pH 6.6 and 6.7).

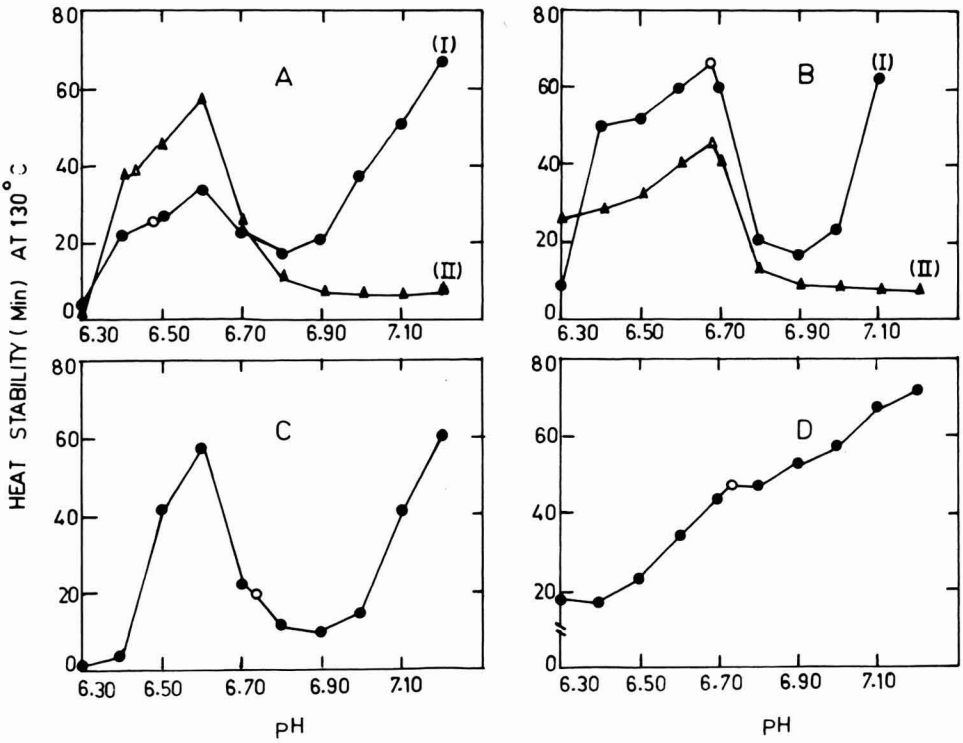

FIG. 4. EFFECT OF pH ON THE HEAT STABILITY OF INDIVIDUAL MILKS FROM KARAN FRIES BREED

A — Type A with maxima at alkaline pH.
1) Sharp minima.
2) Extended minima.

B — Type A milk with maxima at normal pH.
1) Sharp minima.
2) Extended minima.

C -- Type A milk with maxima at acidic pH.

D — Type B milk.

Open symbol denotes the unadjusted (natural) pH.

HCT/pH Profile of Bulk Milk

The type of HCT/pH curves for the bulk milks (pooled milk from not less than 20 animals) from 4 breeds are depicted in Fig. 5, taking one representative sample from each type of HCT/pH profile. As indicated in Fig. 5, with the exception of Karan Fries milk (Graph A in Fig. 5), bulk milks were most stable at a pH which was to the acidic side of natural pH. In Karan Fries milk, some of the smaples had the pH of maximum stability on the acidic side while in others it was at the natural pH itself. Contrary to the individual milks, bulk milks from all the four breeds had a sharp minimum at pH 6.9.

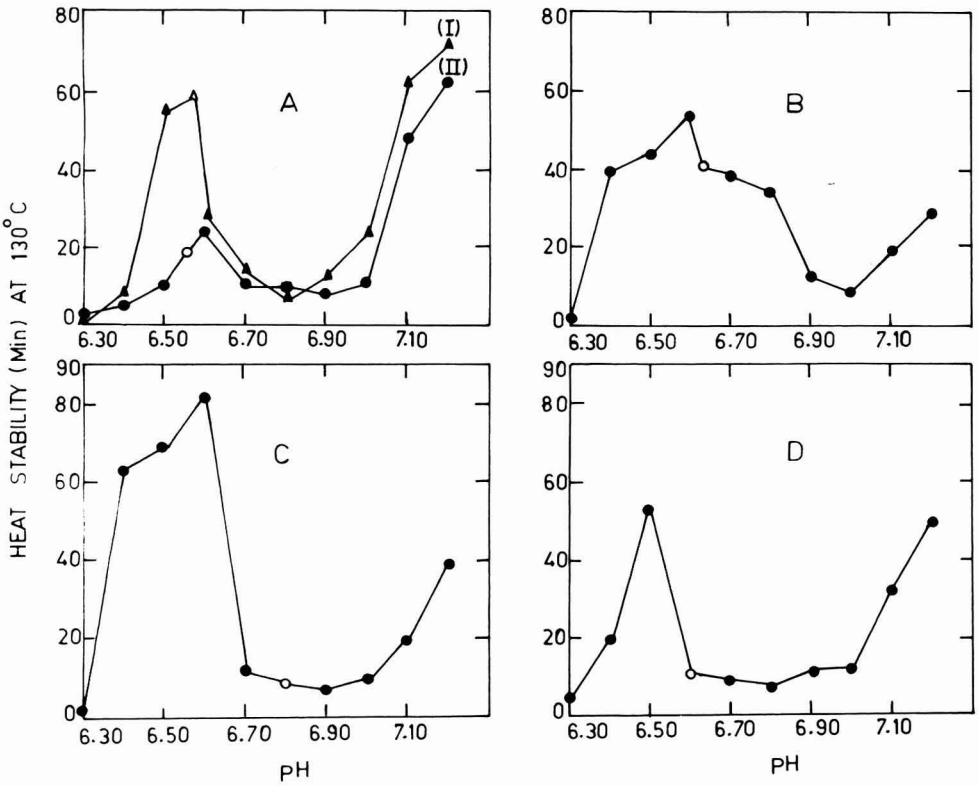

FIG. 5. EFFECT OF pH ON THE HEAT STABILITY OF BULK MILK FROM DIFFERENT BREEDS OF COWS

A — Karan Fries milk.
B — Karan Swiss milk.
C — Sahiwal milk.
D — Tharparkar milk.

Open symbol denotes the unadjusted (natural) pH.

Heat Stability of Milk with Different HCT/pH Profile

According to their HCT/pH profile, all the 85 samples of individual milk from five breeds (3 Zebu and two of their crosses) were divided into 4 groups. The mean values for the HCT and statistically calculated least significant difference (LSD) are presented in Table 2. Statistical analysis on these data revealed that the heat stability of samples belonging to different groups were significantly different ($F = 26.30$ at $P < 0.01$). Type B milk was more stable than any of the Type A milks. In Type A milks those samples in which the pH of maximum stability coincided with natural pH were most stable followed by those in which the

pH of maximum stability was on the alkaline side of natural pH. The type A milk with the maximum stability on the acidic side of natural pH were the least stable.

DISCUSSION

The results on the HCT/pH profile, reveal that the majority of the individual samples from the Zebu cattle were of Type A milk. Of 42 samples of Zebu cattle only one sample of the Sahiwal breed was of Type B. Similarly, in cross bred animals the majority of the samples studied (42 out of 43) were Type A. Studies on the bulk milk from 2 breeds of Zebu cattle (Sahiwal and Tharparkar) and two of their crosses (Karan Swiss and Karan Fries) disclosed that none of the sample was of Type B confirming that most of the individual milks from the 4 breeds were of Type A. Studies in Australia (Feagun *et al.* 1972) and Ireland (Fox 1982) also revealed a very low proportion (only 1%) of Type B milks. However, a much higher proportion, (20%) of Type B milk has been reported from Canada (Tessier and Rose 1964). The majority of the individual milk samples (72%) in Japan are of Type B milk (Fox 1982).

The present results on the occurence of 3 different categories of Type A milk revealed that in Zebu cattle the pH of maximum stability was located on the acidic side of the natural pH in the majority of the samples (all the individual samples of Red Sindhi, 80% of the samples of Sahiwal and 50% of the sample of Tharparkar cows had their maximum stability on the acidic side of the natural pH). The proportion of individual milk samples with the maximum at the natural pH was 10% and 12% on its alkaline side. In milks from exotic breeds different proportions have been reported by various workers for different categories of Type A milks. According to Sweetsur and Muir (1980) in 99% of the samples the maximum stability was on the alkaline side of the natural pH. De Koning *et al.* (1974) observed that in a few of the samples of bulk Dutch milk the pH of maximum stability coincided with the natural pH. While the results of an extensive survey (Holt *et al.* 1978) on the heat stability of bulk Scottish milk confirmed that with the exception of the May and June samples, the pH of maximum stability coincided with the natural pH, and for these two months was on the acidic side of the natural pH. Newstead *et al.* (1975) reported that for much of the year in New Zealand the maximum stability occurred on the acidic side of natural pH.

Cross breeding between the animals of Zebu cattle and exotic breed animals resulted in the alteration of the proportions of milk with different type of HCT/pH profile. In Karan Swiss about 20% of the samples of individual milk were found to have maximum stability at a pH which was on the alkaline side of natural pH while in Sahiwal milk none of the samples exhibited this property. The proportion of samples with maximum stability on the acidic side decreased to 50% due to cross breeding from 80% in the animals of Sahiwal breed. In Karan Fries milks,

TABLE 2

HEAT COAGULATION TIME (HCT) AT NATURAL pH OF INDIVIDUAL MILKS WITH DIFFERENT HCT/pH PROFILE[a]

Sr. No.	Type of milk	No. of samples	pH	HCT (Min) at 130°C
1.	Type A			
	a) Maximum HCT on the acidic side of natural pH	47	6.675	24.03
	b) Maximum HCT at natural pH	15	6.625	63.00
	c) Maximum HCT on the alkaline side of natural pH	21	6.550	54.00
2.	Type B	2	6.750	85.75
	LSD[b]	--	--	6.98 min

a = Individual samples of all the five breeds (3 Zebu and 2 cross breeds) are grouped in this table according to their HCT/pH profile;
b = Statistically calculated least significant difference.

the proportion of samples with the maximum stability on the acidic side of natural pH decreased to 25% from 50% in Tharparkar milk. Statistical analysis of the data (Table 1) revealed that maximum stability of Sahiwal and Tharparker milks was in the pH range of 6.5 to 6.6. The natural pH, 6.67 for Sahiwal and 6.77 for Tharparkar milk was not located in the range of pH of maximum stability. It was on the alkaline side of the pH of maximum stability. The natural pH, 6.77 of Red Sindhi milk was also on the alkaline side of pH of maximum stability (pH 6.6 to 6.7). The HCT of individual milks from all the three breeds at natural pH was significantly lower (LSD values 14.95, 4.34 and 7.21 min, respectively for Sahiwal, Tharparkar and Red Sindhi milks were lower than the differences in the HCT of these milks at natural pH and pH of maximum stability at $P < 0.01$). The analysis of herd milk from Sahiwal and Tharparkar breed also confirmed this fact. As it is evident from graphs C and D in Fig. 5, there was a considerable difference in the heat stability of herd milk at their natural pH and at the pH of maximum stability. Statistical analyses (details for which are not furnished) of herd milk samples revealed that the heat stability of milk from these two breeds was significantly greater ($F = 5.28$ for Sahiwal and 10.25 for Tharparkar milk at $P < 0.01$) at the acidic side of natural pH, due to the location of pH of maximum stability on the acidic side of natural pH in Zebu cattle. The common stabilizers (disodium phosphate and trisodium citrate) are not suitable for it. As in case of buffalo milk it has been observed (Sindhu and Tayal 1984, 1986) that these stabilizers instead of causing stabilization result in strong destabilization of the milk in which the pH of maximum stability is on the acidic side of natural pH. Due to lack of knowledge about the HCT/pH profile of milk from Zebu breeds these stabilizers are in current use in spite of their adverse effect on the stability. The ideal stabilizer for milk from Zebu breeds is monosodium phosphate which results in decrease in pH bringing it to the range of maximum stability.

Statistical analyses (Table 1) revealed that cross breed milk was most stable at natural pH. The maximum stability of individual milks from Karan Swiss was in the pH range of 6.5 to 6.6 while average of their natural pH was 6.6 which was in the range of maximum stability. Therefore, no significant difference was there in the HCT at natural pH and at pH 6.5 where it was maximum. In case of individual milks from Karan Fries breed the maximum stability, 54.75 min was observed at natural pH, 6.65 which was statistically significant ($F = 11.35$ at $P < 0.01$). The herd milk samples from these two breeds exhibited the maximum stability either at natural pH or at a pH which was slightly acidic to natural pH (Graphs A and B, Fig. 5). However, in those samples of herd milk in which it was on the acidic side of natural pH there was no significant difference in the HCT at natural pH and at pH where it was highest (details for statistical analyses of herd milk are not furnished). Therefore, it can be concluded that cross breeding of Zebu cattle (Sahiwal and Tharparkar) with the animals of exotic breeds (Brown Swiss and Holstein Friesian) resulted in change in the HCT/pH profile of their milks (from Type A with maximum on the acidic side of natural pH to Type A with maximum at natural pH).

The role of Type of HCT/pH profile of milk in its stability has not yet been investigated by any worker. In Table 2 we classified all the individual samples of milk from five breeds according to their Type of HCT/pH profile in 4 groups to determine its effect in the stability of milk. The statistical analyses of these data established that there was a significant difference ($F = 6.98$ at $P < 0.01$) in the heat stability of milks having different type of HCT/pH profile. Type B milk was most stable followed by Type A with maximum stability at natural pH and than Type A with maximum in the alkaline side of natural pH. The Type A milk with maximum stability on the acidic side of natural pH was the least stable. On the basis of these results it can be concluded that the stability of milk from a particular animal is dependent on its type of HCT/pH profile. Further, as it has been observed in case of cross breed milk the HCT/pH profile of a milk depend on genetic factors. Therefore, through selective cross breeding it is possible to produce milk of desired HCT/pH profile with better stability.

REFERENCES

DAVIES, D. T. and WHITE, J. C. D. 1966. The stability of milk proteins to heat. I. Subjective measurement of heat stability of milk. J. Dairy Res. *33*, 67-81.

DE KONING, P. J., KOOPS, J. and ROOUEN, P. F. 1974. Some features of the heat-stability of concentrated milk. III. Seasonal effect on the amounts of casein, individual whey proteins and NPN and their relations to variations in heat stability. Netherland Milk and Dairy J. *27*, 186-202.

FEAGAN, J. T., BAILEY, L. F., HEHIR, A. F., McLEAN, D. M. and ELLIS, N. J. S. 1972. Coagulation of milk proteins. I. Effects of genetic variants of milk proteins in rennet coagulation and heat stability of normal milk. Australian J. Dairy Technol. *27*, 129-134.

FOX, P. F. 1981. Heat induced changes in milk preceding coagulation. J. Dairy Sci. *64*, 2128-2137.

FOX, P. F. 1982. *Developments in Dairy Chemistry. I. Proteins.* Applied Science Publishers, London, New York.

GRIFFIN, A. T., HICKEY, M. W., BAILEY, L. F. and FEAGAN, J. T. 1976. The significance of preheating and pH adjustment in the manufacture of recombined evaporated milk. Australian J. Dairy Technol. *31*, 134-137.

HOLT, C., MUIR, D. D. and SWEETSUR, A. W. M. 1978. The heat stability of milk and concentrated milk containing added aldehydes and sugars. J. Dairy Res. *45*, 47-52.

JAIRAM, B. T., VIJAYLAXMI, B. T., BALAKRISHNAN, C. R., NAIR, K. G. S. and NAIR, P. G. 1976. A study on the heat stability of cows milk using indigenous device. Indian J. Dairy Sci. *27*, 222-226.

NEWSTEAD, D. F., SANDERSON, W. B. and BAUCKE, A. G. 1975. The effect of heat treatment and pH on the heat stability of recombined evaporated milk. New Zealand J. Dairy Sci. *10*, 113-118.

SINDHU, J. S. 1985. Effect of sodium phosphate on the heat stability of buffalo milk and its concentrate. J. Food Proc. and Pres. *9*, 57-64.

SINDHU, J. S. and TAYAL, M. 1984. Effect of sodium citrate on the heat stability of buffalo milk and its concentrate. Food Chem. *15*, 57-62.

SINDHU, J. S. and TAYAL, M. 1986. Effect of stabilizers on the salt balance of pH of buffalo milk and its concentrate. J. Food Technol. *21*, 331-337.

SWEETSUR, A. W. M. and MUIR, D. D. 1980. The use of permitted additives and heat treatments to optimise the heat stability skim milk and concentrated milk. J. Society Dairy Technol. *33*, 101-105.

TESSIER, H. and ROSE, D. 1964. Influence of K-casein and B-lacto-globulin on the heat stability of skim milk. J. Dairy Sci. *47*, 1047-1051.

OSMOTIC DEHYDRATION OF FRUIT

PART 2: INFLUENCE OF THE OSMOSIS TIME ON THE STABILITY OF PROCESSED CHERRIES

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ABSTRACT

Influence of the osmosis time on the stability of processed cherries ("Vittoria", "Durone Nero I" and "Starking" cultivars) was studied.

The cherries were osmo-dehydrated for two, four, six hours, vacuum packed, pasteurized and then analyzed for ascorbic acid, glucose, fructose and maltose content by HPLC, for pH, total titrimetric acidity, dry matter, color and for organoleptic characteristics, during the process and up to six months of storage.

The dehydration of the fruit and the exchange with the osmotic syrup took place chiefly during the first two hours of the process. No substantial differences were noted though, in the cherries, processed at different time, both for chemical and organoleptic characteristics. Color data showed the importance of the variety in order to obtain good products. Thus it was concluded that a two hours' osmo-dehydration process is suitable to achieve very acceptable products.

INTRODUCTION

As pointed out in the first part of this work by Giangiacomo *et al.* (1986), osmotic dehydration has recently received attention as an intermediate step in drying, dehydrofreezing and freeze-drying (Pontig *et al.* 1966; Farkas and Lazar 1969; Hope and Vitale 1972; Pontig 1973; Lerici *et al.* 1977; Hawkes and Flink

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1978; Lerici and Riva 1985). Moreover Maltini and Torreggiani (1981) and Maltini *et al.* (1983) proposed to use osmotic dehydration in order to obtain high water activity fruit products (a_w = 0.94-0.97) which, after a 6 h osmotic dehydration, vacuum-packaging and pasteurization, remained stable for many months at ambient temperature.

In this type of technology there is no primary stabilization process such as sterilization or freezing. The stabilization of the product is achieved by using numerous factors like lowering water activity, pH and E_h, ascorbic acid enrichment and bland thermal treatment, Leistner *et al.* (1976).

The a_w lowering isn't the unique factor affecting the shelf-life of this product and furthermore the most consistent changes in its composition occurred in about two hours of process (Hawkes and Flink 1978; Giangiacomo *et al.* 1986). So in this work the possibility of reducing the osmosis time was studied.

Three cultivars of cherries, chosen after preliminary tests, were osmotically dehydrated for two, four and six hours at ambient temperature. Then the fruits were evaluated for their chemical, chemical-physical and organoleptic characteristics both during the process and the storage at ambient temperature.

MATERIALS AND METHODS

Fruit and Osmotic Process

The following varieties of cherries were used: "Vittoria", "Durone Nero I", "Starking", harvested at a commercial maturation stage. Cherries, stemmed (except for "Vittoria" cv. harvested without stem) and pitted, were water-blanched at 70°C for 120 s: in this condition only the thermal destruction of the surface microorganisms was obtained, but not the inactivation of enzymes. The fruit were then dehydrated using a 70°Bx syrup consisting of corn syrup (24% glucose, 29% maltose, 12% polysaccharides, 35% water)/sucrose/water, (5/3/1), (w/w/w), and containing ascorbic acid (1%) as an antioxidant agent. The dehydration was carried out at an ambient temperature of 25°C approximately for 2, 4 and 6 h. After the osmotic concentration the fruit were drained, vacuum packed in plastic pouches (Doypack-Grace 250 g), pasteurized (75°C for 30 min) cooled and stored at an ambient temperature of approximately 25°C.

Analytical Methods

The investigations were conducted on raw fruit, after blanching, after osmosis and after two, four and six months of storage. Each sample consisted of the contents of three bags and each analysis was repeated twice. Samples were analyzed for ascorbic acid, sugars (glucose, fructose, maltose), pH, total acidity, dry matter, color and for organoleptic characteristics.

The ascorbic acid was quantified by HPLC (Rizzolo *et al.* 1984). The sugars were determined by HPLC by using a Jasco Twincle Liquid Chromatograph, equipped with a column Lichrosorb NH_2 10 μm (250 × 4mm I.D.) Merck and coupled to a Shodex RI SE 11 Differential Refractometer Detector and a Shimadzu Chromatopack C-R1B Data Processor. The chromatograph was operated at room temperature with acetonitrile/water (80/20) as the eluting solvent adjusted to a rate of 1.4 mL/min. A 1% aqueous solution of α-methyl-D-glucoside was used as an internal standard. The sugars were extracted by homogenizing 10 g of sample in a 100 mL centrifuge tube with 40 mL of a mixture of ethanol/water (50/50). After 10 min the suspension was centrifuged at 6000 rpm and the extract was transferred into a 100 mL volumetric flask. The procedure was followed through once more and the two extracts were joined and the volume was brought to the mark with ethanol/water. Before injecting the extract was filtered on a Millipore membrane filter HA 0.22 μm. The standard error was ranging from 0.02 to 0.05.

Total titratable acidity, pH and percent of dry matter were carried out according to AOAC methods (1980).

Hunter color measurements were determined on a Hunterlab Color Difference Meter DM25. The readings were made on a double layer of fruit; reported data are the mean of five determinations. From Hunter values of a, b and L the color difference ΔE of the products after two, four and six months of storage, was calculated from the formula, (Hunter 1975):

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$$

Sensory Evaluation

Sensory evaluations were carried out through a preference test (Larmond 1977), by using a nine-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely) and taking into account appearance, flavor and texture. The panel was composed of 10 semitrained judges and each tasting was repeated twice in subsequent days. Analysis of variance and Duncan's multiple range test were used to determine statistically significant differences ($P \leqslant 0.05$).

Material Balance During the Osmosis

The difference between the amount of ascorbic acid or individual sugars in the fruit before the treatment (Co) and that present at the time of sampling (Ct), divided by the initial weight (Po), was calculated according to Hawkes and Flink (1978):

$$\Delta C = \frac{Ct - Co}{Po} \times 100$$

RESULT AND DISCUSSION

Process

The percentage of dry matter, total acidity, ascorbic acid and pH values are shown in Table 1 for the raw fruit and in Table 2 for the blanched ones. No significant changes for these parameters are observed during this first stage of the process.

TABLE 1
ANALYTICAL DATA OF FRESH FRUIT

			on dry matter				
Fruit	Dry matter (%)	pH	Ascorbic acid (mg/100g)	Fructose (%)	Glucose (%)	Total sugars (%)	Total acidity (meq/100g)
"Vittoria"	17.65	3.9	3.0	24.59	46.80	71.39	12.51
"Durone Nero I"	19.82	3.6	45.0	25.43	47.98	73.41	14.51
"Starking"	16.18	3.7	4.4	27.56	51.17	78.73	13.41

The percentage of dry matter and the weight losses of the fruit after the osmotic treatment are shown in Table 3, while the percent dry matter increases during the process are reported in Fig. 1. The data confirmed that the maximum mass exchange takes place within the first two hours of the treatment, (Hawkes and Flink 1978; Giangiacomo *et al.* 1986). Moreover the three cultivars had a similar behavior with regard to the dry matter changes.

Table 4 shows the balance of ascorbic acid and sugars during the osmosis. After 2 h the ascorbic acid penetration ranged between 80 and 100 mg/100 g of fresh fruit. During the next two hours ascorbic content increased very little for the cultivar "Durone Nero I," and of 24% for the other two cultivars. In the last 2 h of the process all increments ranged between 0% and 15%. Owing to the composition of the osmotic syrup the sugars uptake was much higher (from 2

TABLE 2
ANALYTICAL DATA OF FRUIT AFTER BLANCHING

Fruit	Dry matter (%)	pH	on dry wt. Ascorbic acid (mg/100g)	Fructose (%)	Glucose (%)	Total sugars (%)	Total acidity (meq/100g)
"Vittoria"	17.41	3.8	6.0	24.30	46.50	70.80	14.30
"Durone Nero I"	20.26	3.6	60.0	25.10	47.19	72.29	15.20
"Starking"	15.90	3.7	4.0	27.98	52.25	81.24	15.10

to 5 g/100 g of fresh fruit) than that of the ascorbic acid: glucose and fructose increased between 0.3 and 3% for all the cultivars tested and the osmosis time seemed not to influence this exchange. Otherwise the maltose, not previously found in the raw fruit, showed a slight increase related to the osmosis time.

The pH values of the fruit before and just after osmosis (zero months of storage in Table 1 and Table 5, respectively), didn't have significant differences. A decrease in the total titratable acidity (Table 5) was noted for all the samples according to many researches on the osmotic dehydration of different fruit.

From sensory evaluations (Fig. 2) concerning appearance, flavor and texture of the fruit just processed, it was observed that there were no significant differences, among the different times of osmosis, for all the characteristics examined. However differences were found among the cultivars: in fact the "Vittoria" cherries were preferred by the panelists both for appearance and flavor. As for texture, the sensory acceptance was the same for all the cultivars tested.

Storage

Figure 3 shows the ascorbic acid contents of the processed cherries during the storage. The amounts of ascorbic acid, just after the different osmosis times, ranged between 420 mg and 560 mg/100 g (dr.wt.) in all the cultivars.

TABLE 3
DRY MATTER AND WEIGHT LOSS OF THE FRUIT AFTER THE OSMOTIC PROCESS

Fruit	Time of process (hrs)	Dry matter (%)	Weight loss (%)
"Vittoria"	2	25.82	24.61
	4	29.76	31.42
	6	31.97	36.30
"Durone Nero I"	2	26.90	10.04
	4	29.04	16.52
	6	31.81	21.71
"Starking"	2	26.13	16.42
	4	30.31	25.00
	6	32.77	31.40

During the first four months there was a decrease in the ascorbic acid for all the samples, while, in the last two months, a further decrease was found only for the 6-h processed "Vittoria" and for the 4-h processed "Starking." At the end of the storage, the ascorbic contents of cv. "Vittoria" and cv. "Durone Nero I" were 45%-50% with respect to the initial amount; cv. "Starking" showed slight differences among the samples osmodehydrated for different times.

The sugars contents of the processed cherries are shown in Fig. 4. Just after the osmosis, the fructose amount was about 22 g-23 g/100 g (dr.wt.) for all the cultivars and this value was not affected by the storage. The glucose amount ranged between 45% and 52% (dr.wt.) and slightly decreased during preservation for all the cultivars. Maltose content ranged between 4% and 8% all through the storage period for "Durone Nero I" and "Starking," whereas slightly decreased for "Vittoria."

The different osmosis times seemed not to affect the sugars content. This is pointed out in Fig. 5, reporting the percentage of total sugars of the processed cherries changes during the storage. After six months, the "Vittoria" showed

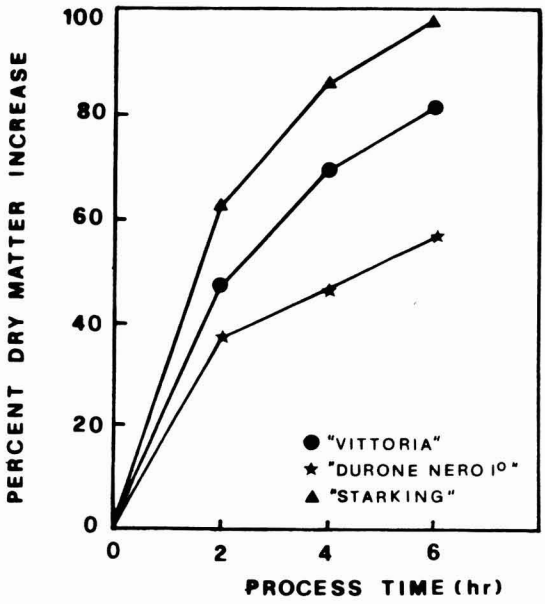

FIG. 1. PERCENT DRY MATTER INCREASE DURING THE OSMOTIC PROCESS
(all values are referred to as the initial content of dry matter)

a total sugars content ranging from 75% to 80% of the initial value, while the "Durone Nero I" and the "Starking" from 80% to 95%.

The pH values showed no significant changes, while there was a decrease in total titratable acidity (Table 5). The residual acidity, Fig. 6, was 55%-70% of the initial amount for "Vittoria" cherries; while it was 80% and 90% for "Durone Nero I" and "Starking," respectively.

An influence on acidity, ascorbic acid and sugars contents of the different osmosis times, was not observed.

The Hunter L, a, b color values of processed cherries are shown in Fig. 7. It was noted by a decrease in saturation ($\sqrt{a^2 + b^2}$) and a hue modification from red to yellow. These changes were lower for cv. "Vittoria" than for the other two. With regard to lightness (L), in "Vittoria" this parameter was almost constant, while for the other two cvs. L showed a progressive increase, especially within the first two months of storage. These changes caused a lightening of the products. Figure 8 shows the color differences (ΔE) of the processed cherries, referring to the zero months of storage, and the analysis of variance results. The ΔE values of the three times of osmosis, within the same month of storage and the same cultivar, are significantly different in almost all the cases, but not perceptible by the eye; while strong differences were noted between ΔE values of different cultivars during the storage for the same osmosis time.

The results of sensory evaluation of the processed cherries are shown in Fig. 2. There was a different behavior among the cultivars and the color was undoubtedly

TABLE 4
BALANCE OF ASCORBIC ACID AND SUGARS DURING THE OSMOSIS; ALL VALUES ARE REFERRED TO 100 g OF FRESH FRUIT BEFORE THE OSMOSIS

		Δ C (%)				
Fruit	Osmosis time (hrs)	Ascorbic acid (mg/100g)	Glucose (%)	Fructose (%)	Maltose (%)	Total sugars (%)
"Vittoria"	2	89.9	0.5	1.4	1.2	3.1
	4	102.9	0.3	0.9	1.5	2.7
	6	110.2	0.3	2.1	1.8	4.6
"Durone Nero I"	2	108.0	0.9	2.4	1.1	4.4
	4	114.3	- 0.5	- 0.4	0.9	0.0
	6	131.5	0.6	2.0	1.4	4.0
"Starking"	2	96.9	0.5	1.2	0.7	2.4
	4	120.7	1.2	3.1	1.5	5.8
	6	120.0	0.8	2.5	1.9	5.2

the critical parameter. In fact, as regard to the appearance, at the end of the process, the sensory acceptance of the "Durone Nero I" cv., was just below standard and the one of the "Starking" cv. barely sufficient, with no differences among the times of osmosis. The appearance of both these cultivars, however, increasingly got worse during the storage, showing statistical significant differences with the values of zero months of preservation, Fig. 2; so the sensory acceptance of the products was very low even from the fourth month of storage. On the contrary, good scores for appearance were obtained by "Vittoria" cv. all through the storage period and for all the osmosis times considered. As regard to the flavor, the sensory acceptance had a similar trend: "Vittoria" cv. were judged sufficient, while the other two cultivars were not. These judgments didn't significantly change during the storage.

TABLE 5
pH AND ACIDITY CONTENTS OF FRUIT AFTER THE OSMOSIS AND DURING THE STORAGE
*(meq/100 g dry wt.).

Fruit	Storage period (months)	Osmosis time (hrs)					
		2		4		6	
		pH	Acidity*	pH	Acidity	pH	Acidity
"Vittoria"	0	3.75	34.53	3.75	35.31	3.65	32.34
	2	4.10	27.81	4.00	23.43	4.00	23.43
	4	3.95	27.03	3.90	24.84	3.83	21.09
	6	3.78	23.90	3.53	19.06	3.53	22.19
"Durone Nero I"	0	3.60	50.00	3.60	45.31	3.50	46.86
	2	3.80	45.31	3.80	39.06	3.80	39.06
	4	3.80	46.87	3.85	43.75	3.81	32.81
	6	3.72	40.47	3.78	36.87	3.78	41.09
"Starking"	0	3.60	34.37	3.60	35.93	3.60	25.31
	2	3.75	34.00	3.83	28.12	3.75	14.06
	4	3.85	33.81	3.81	29.68	3.75	29.68
	6	3.80	33.60	3.75	31.56	3.74	31.56

Texture was not affected by the osmosis process, except for "Starking" cv., which showed a statistical significant worsening during storage. As regard to the texture, the other two varieties showed a sensory acceptance sufficient all through the preservation period.

CONCLUSION

By testing three different osmotic dehydration times on three cultivars of cherries, it was emphasized the importance of some physical, chemical, technological

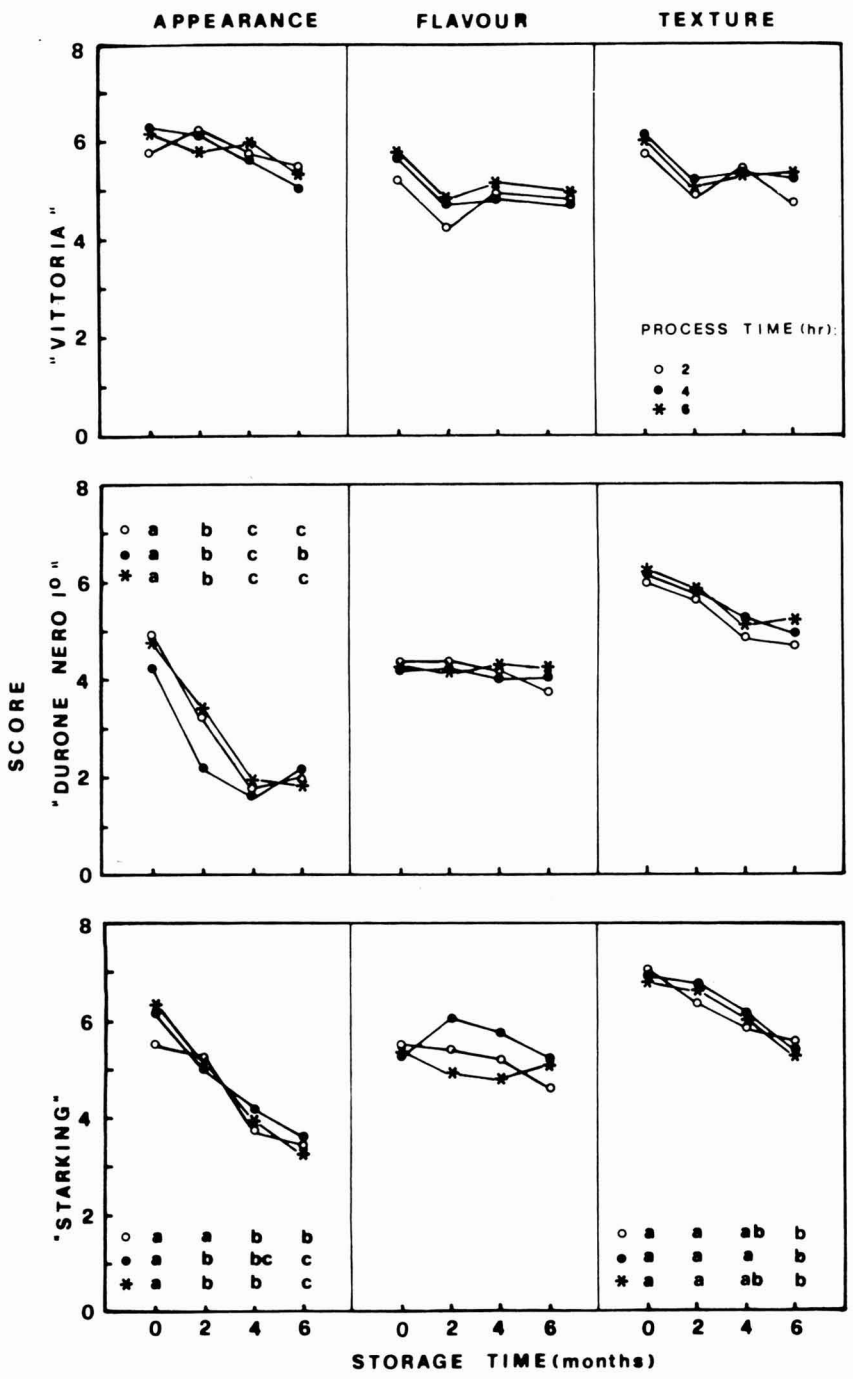

FIG. 2. SENSORY EVALUATIONS OF THE PROCESSED CHERRIES DURING STORAGE

*Mean values, at the same process time, within storage period, which are without or followed by the same letters are not significantly different ($P \leqslant 0.05$).

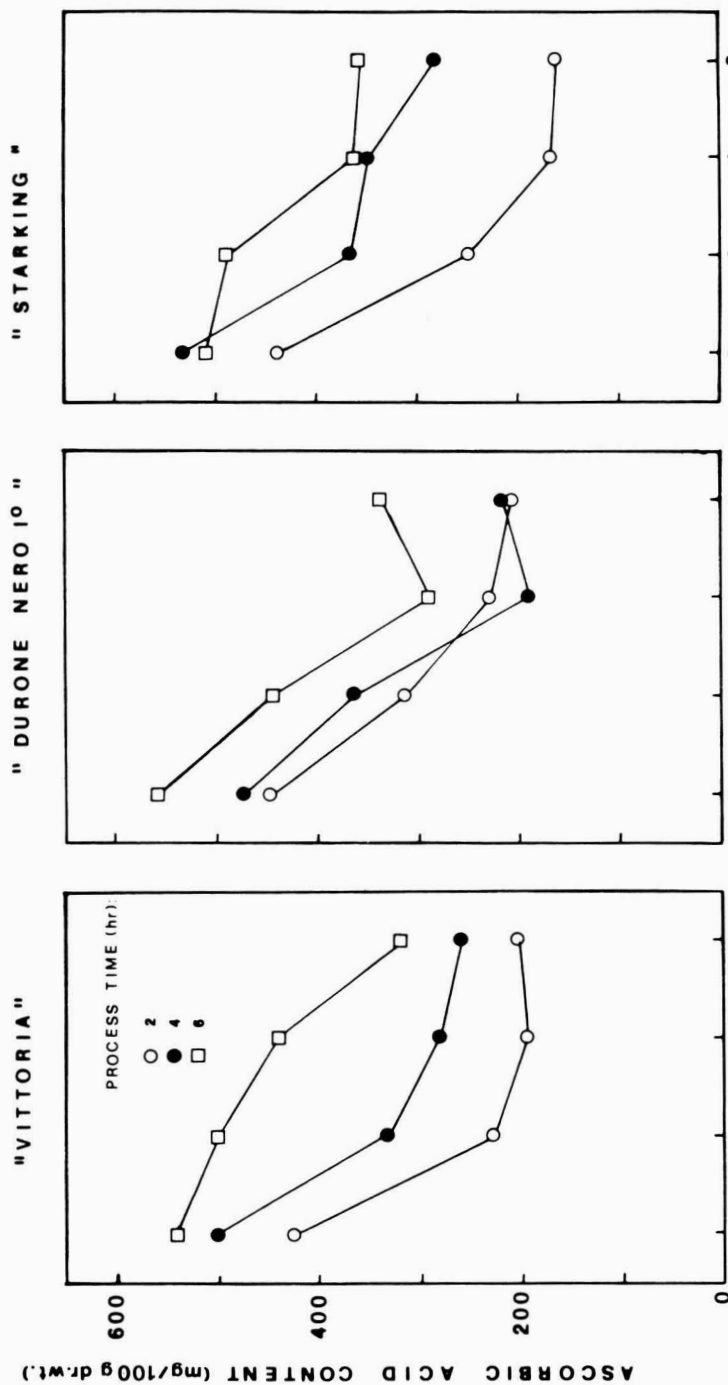

FIG. 3. ASCORBIC ACID CONTENT OF THE PROCESSED CHERRIES DURING THE STORAGE

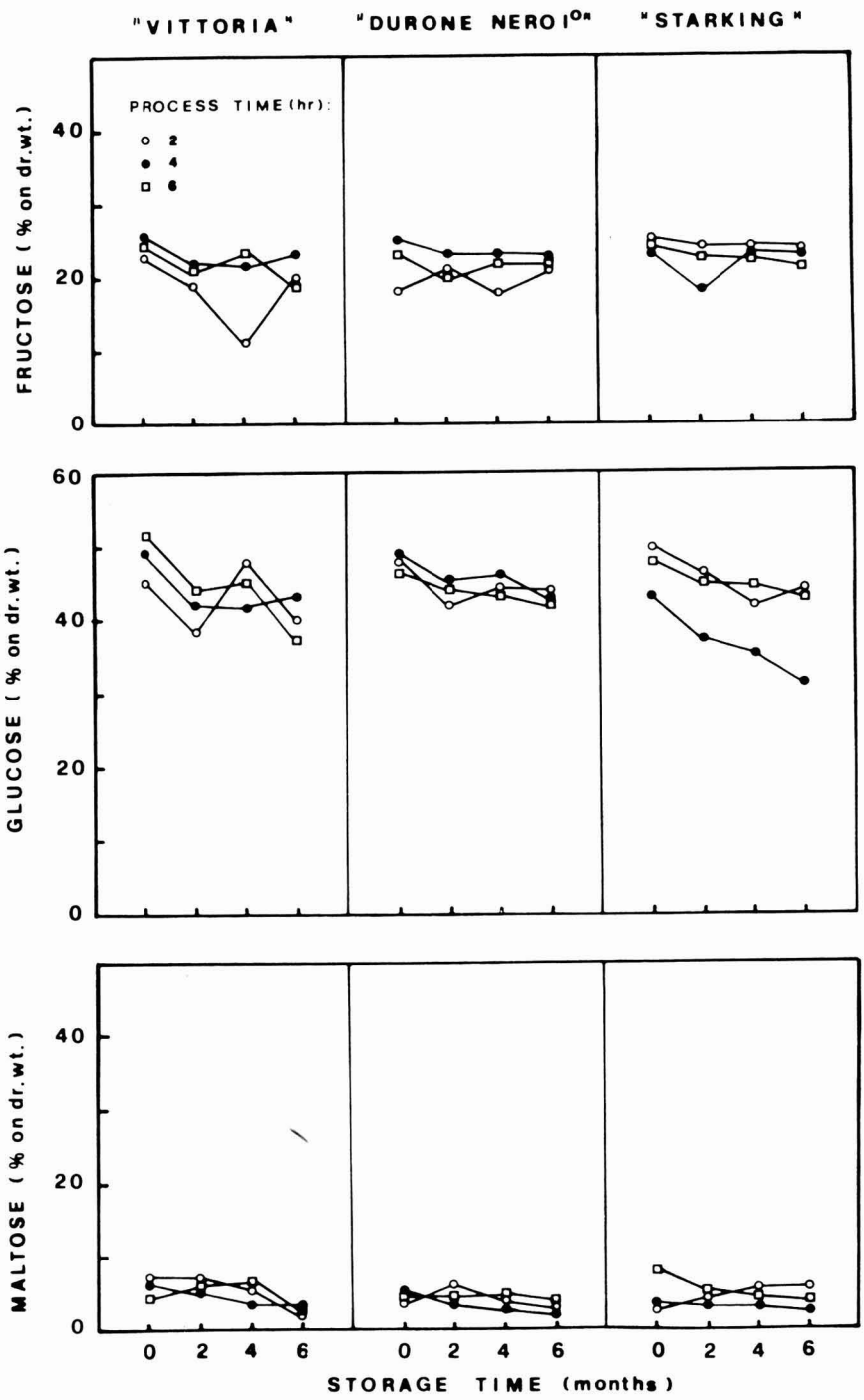

FIG. 4. SUGARS CONTENT OF THE PROCESSED CHERRIES DURING THE STORAGE

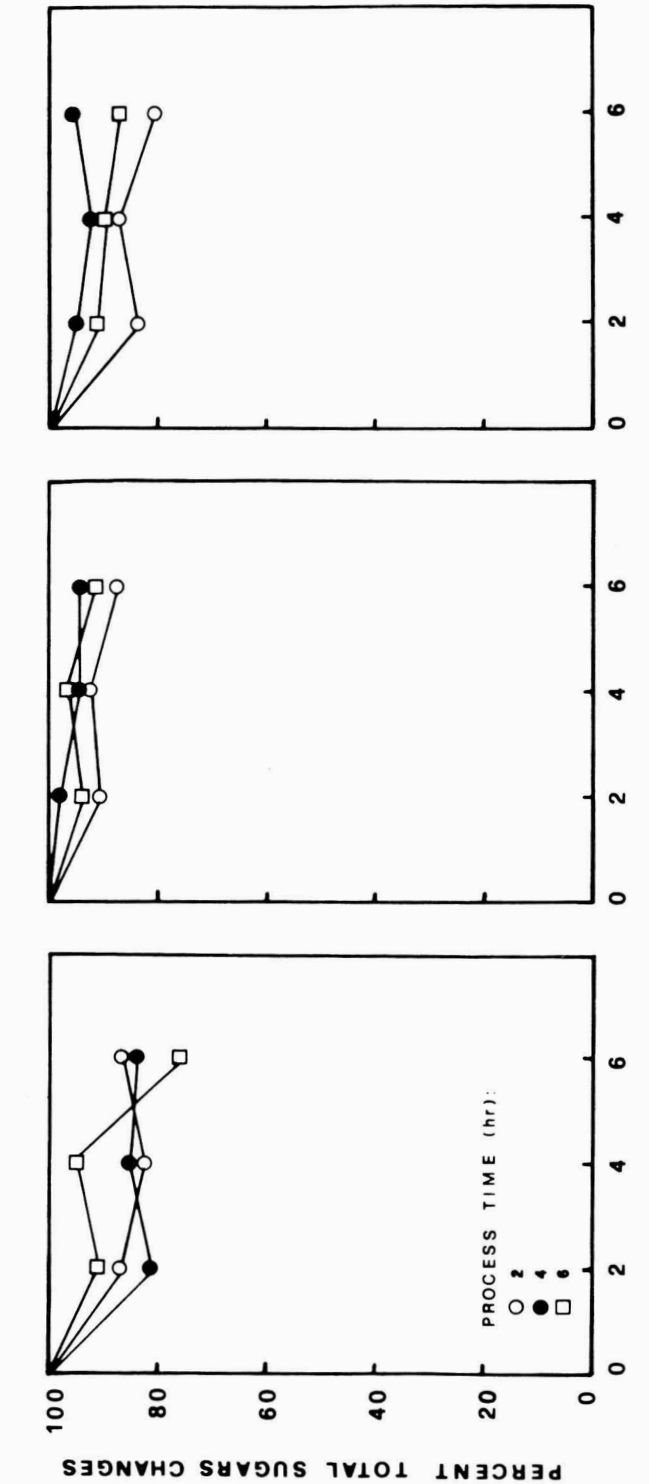

FIG. 5. PERCENT TOTAL SUGAR CHANGES OF THE PROCESSED CHERRIES DURING THE STORAGE

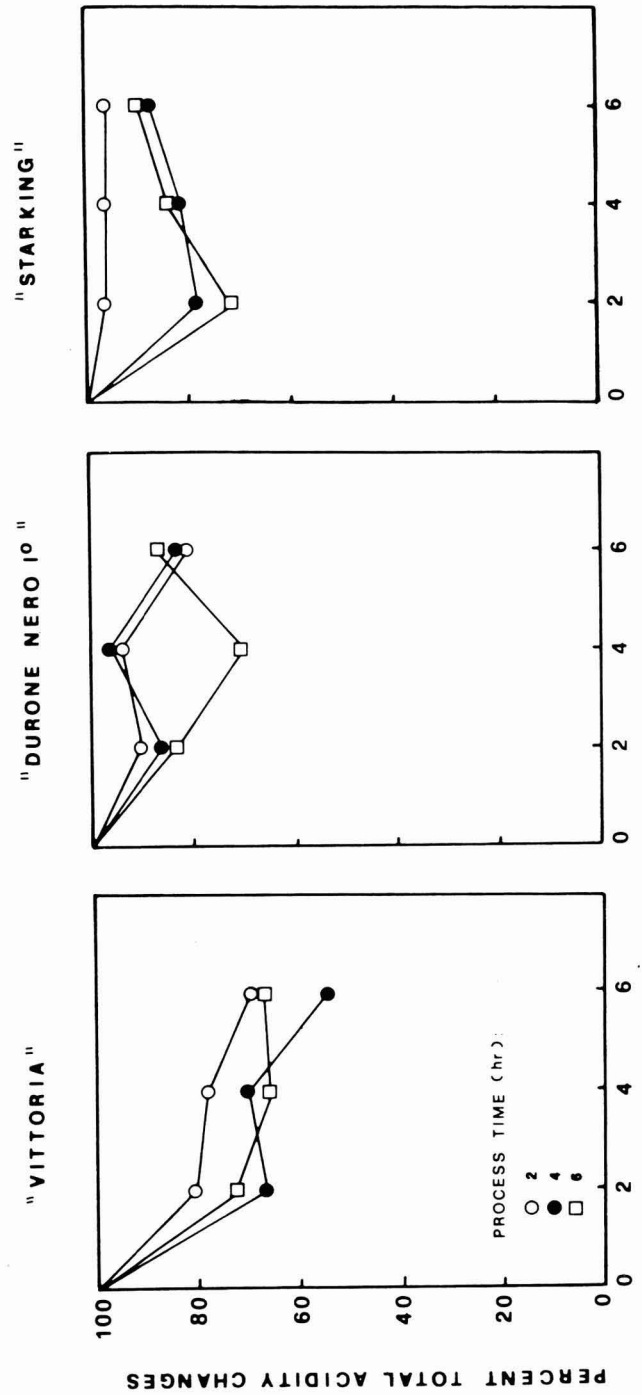

FIG. 6. PERCENT TOTAL ACIDITY CHANGES OF THE PROCESSED CHERRIES DURING THE STORAGE

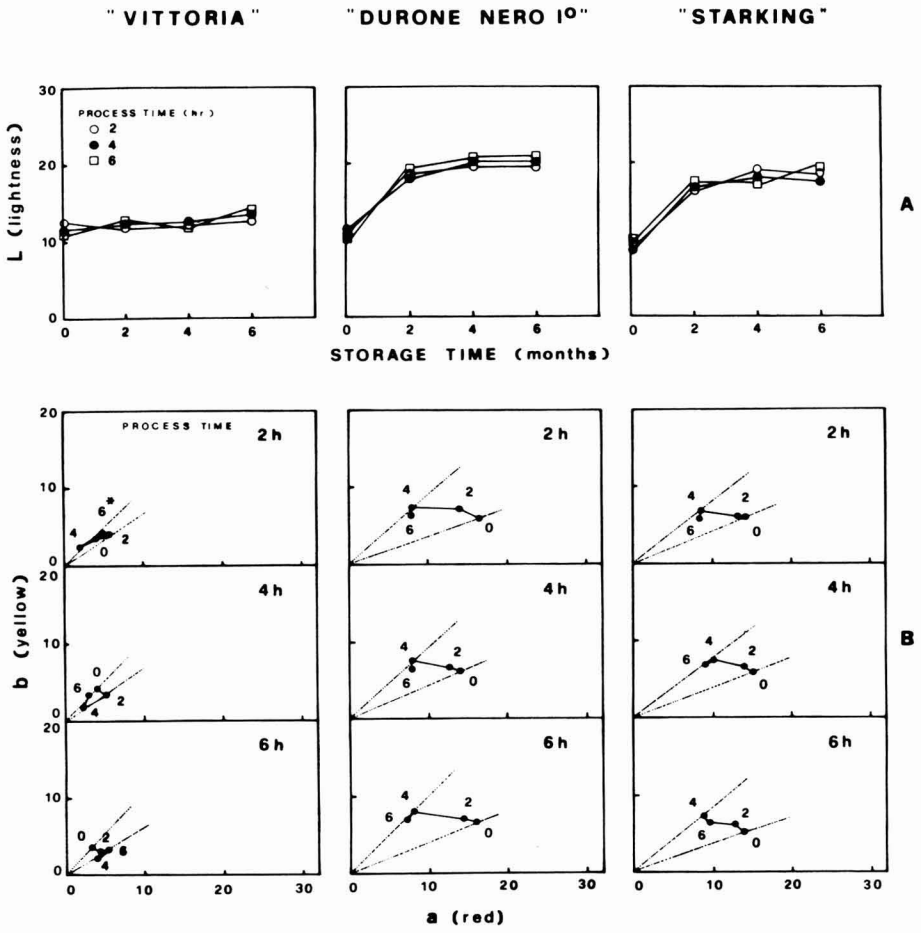

FIG. 7. HUNTER L, a, b VALUES OF THE PROCESSED CHERRIES DURING STORAGE:
A: LIGHTNESS (L); B: TWO-DIMENSIONAL CHROMATICITY DIAGRAMS
*Months of storage.

parameters to obtain products of good quality and with a good shelf-life at ambient temperature.

It was confirmed that the water loss and the penetration of sugars and ascorbic acid into the fruit mainly occurred during the first two hours of process. Moreover, from the sensory evaluation tests, no significant differences were found between the different samples just after the osmosis.

Whatever the osmosis times were, the products obtained showed a similar behavior as regard to the ascorbic acid, sugars and total acidity over the six months of storage.

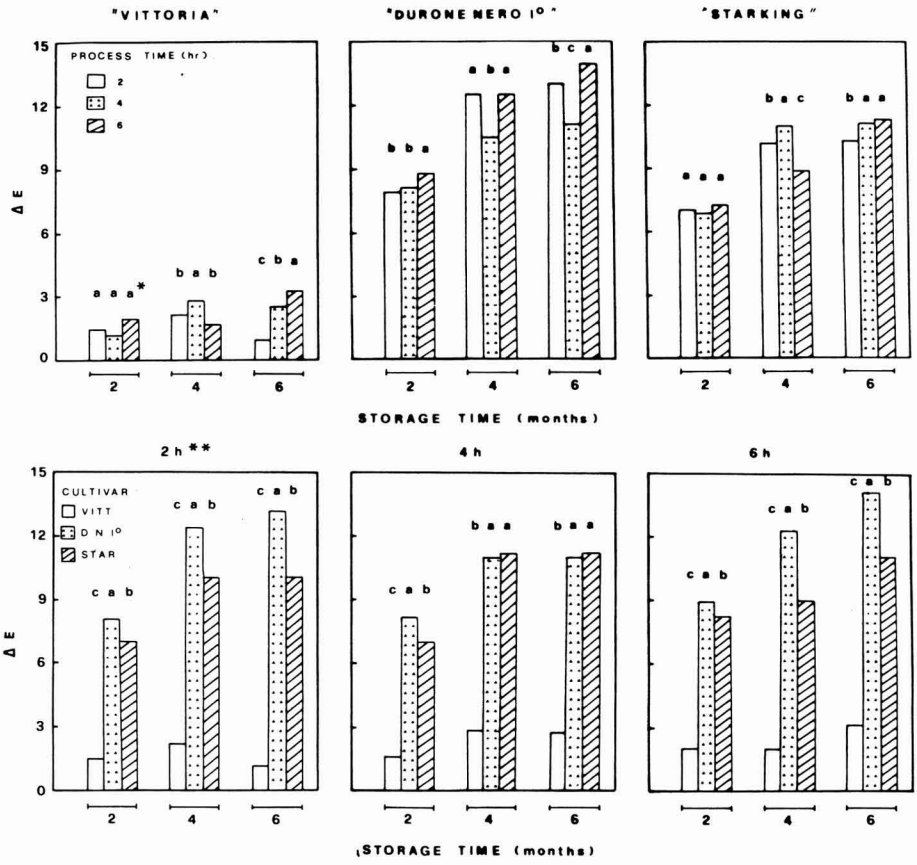

FIG. 8. TOTAL COLOR DIFFERENCES OF THE PROCESSED CHERRIES, REFERRING TO THE ZERO MONTHS OF STORAGE

*Mean values not followed by the same letters are significantly different ($P \leq 0.05$).
**Process time (hours).

With respect to the most suitable cultivar of cherries for the osmotic dehydration, the chemical analyses didn't show any difference among the cultivars tested during processing, except for the higher amounts of ascorbic acid in cv. "Starking" and of sugars and total acidity in cvs. "Durone Nero I" and "Starking."

Sensory acceptance for flavor and texture was good for all the times of the osmosis analyzed; whereas the one of appearance was not affected by the osmosis time, but by the cultivar. In fact, among the cultivars tested, only the "Vittoria" appearance was acceptable to the standards and the products obtained were of good quality.

Further research should enable us to find some other cultivars with a good color stability all through the process and the storage period.

The results of this work showed that two hours of osmotic dehydration is enough to obtain an acceptable product, with good quality and shelf-life at ambient temperature.

REFERENCES

AOAC. 1980. Official Methods of Analysis. 13th Ed. AOAC, no. 46.024-22.061-22018, Washington, D.C.

DIXON, G. M. and JEN, J. J. 1977. Changes of sugars and acids of osmovac-dried apple slices. J. Food. Sci. *42*, 1126-1127.

FARKAS, F. and LAZAR, M. E. 1969. Osmotic dehydration of apple pieces: effect of temperature and syrup concentration. Food Technol. *23*, 668-690.

GIANGIACOMO, R., TORREGGIANI, D. and ABBO, E. 1986. Osmotic dehydration of fruit. Part 1. Sugar exchange between fruit and extracting syrups. J. Food Proc. Pres. *11*, 183-195.

HAWKES, J. and FLINK, J. M. 1978. Osmotic dehydration of fruit slices prior to freeze-dehydration. J. Food Proc. Pres. *2*, 265-284.

HOPE, G. W. and VITALE, D. G. 1972. Osmotic dehydration. Int. Devel. Res. Cent. Monog., IDRC-004e, pp. 12, Canada Dept. Agric., Food Res. Inst., Ottawa, Canada.

HUNTER, R. S. 1975. Scales for the measurements of color differences. In *The Measurements of Appearance*, pp. 133-140, John Wiley & Sons, New York.

LARMOND, E. 1977. Laboratory methods for sensory evaluation of food. Res. Branch Canada Dept. Agric., Pub. 1637.

LEISTNER, L. and RODEL, W. 1976. The stability of intermediate moisture foods with respect to microorganisms. In *Intermediate Moisture Foods*, (R. Davies, G. G. Birch, and K. J. Parker, eds.) pp. 120, Applied Science Publ. Ltd., London.

LERICI, C. R., PEPE, M. and PINNAVIVA, G. 1977. La disidratazione della frutta mediante osmosi. Ind. Conserve, *52*, 125-129.

LERICI, C. R. and RIVA, M. 1985. Principi ed applicazioni della disidratazione osmotica. In *Progressi delle Tecniche di Disidratazione di Frutta e Ortaggi.* Monog. n. 4, pp. 129-161, CNR-IPRA, Roma, Italy.

MALTINI, E. and TORREGGIANI, D. 1981. A new application of osmosis: the production of shelf stable fruit. Proc. 246th Event Europ. Fed. Chem. Eng., pp. 55, Milan, Italy.

MALTINI, E., TORREGGIANI, D., BERTOLO, G. and STECCHINI, M. 1983. Recent developments in the production of shelf-life stable fruit by osmosis. Proc. 6th Int. Congr. Food Sci. Technol., *1*, 177-178, Dublin, Ireland.

PONTIG, J. D. 1973. Osmotic dehydration of fruit: recent modifications and applications. Process. Biochem. *8*, 18-20.

PONTIG, J. D., WATTERS, G. G., FORREY, R. R. and STANLEY, W. L. 1966. Osmotic dehydration of fruit. Food Technol. *29*, 125-128.

RIZZOLO, A., FORNI, E. and POLESELLO, A. 1984. HPLC assay of ascorbic acid in fresh and processed fruit and vegetables. Food Chem. *14*, 189-199.

THE INFLUENCE OF CURING INGREDIENTS, PACKAGING METHOD AND STORAGE ON THE BIOCHEMICAL AND SENSORY QUALITIES AND ACCEPTABILITY OF A DRIED BEEF PRODUCT[1]

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ABSTRACT

A stable, tender, cured, dried beef product was developed using a pressure cooking and accelerated drying technique. The effects of nitrate, packaging methods and storage time on the sensory properties, residual nitrite, TBA values and microbiological counts were determined. Residual nitrite was significantly reduced in nonvacuum compared to vacuum packaged samples and was reduced by storage time but was not influenced by the addition of nitrate. TBA values were not affected by nitrate of vacuum packaging, but increased significantly with storage time. Flavor scores were slightly less desirable in vacuum packaged product and decreased with storage time. The dried beef was acceptable even at the sixth-week storage period. Total aerobic plate counts were very low and no anaerobic bacteria was detected in any of the dried beef samples. A product produced by this technique without nitrate handled in this manner of post cooking and vacuum packaged would appear to be useful in a high ambient temperature for at least up to 6 weeks.

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INTRODUCTION

In the Philippines, a shelf-stable dried beef is made from fresh uncooked lean beef which is sliced 3-4 mm thickness, salted, and arranged on bamboo slatted trays. The meat slices are dried under the sun to approximately 10-12% moisture. The dried beef is pan fried in vegetable oil before it is eaten with rice; served as a snack food with soft drinks, or more often served with cocktails during dinner parties. If a similar product could be made from meat of older animals, it might lead toward a more efficient utilization of the available meat in the Philippines.

This research was conducted to develop and evaluate a stable more tender than provential (previously described) product, produced from older animals, which can be stored at the high temperature and humidity that exists in tropical countries. In addition, the effect of nitrate, packaging method, and storage time on the sensory properties, residual nitrite, TBA values and microbiological counts of dried beef produced by this method were evaluated.

MATERIALS AND METHODS

Preparation of Sample

Lean beef from the chuck clod (deltoideus and infraspinatus muscles) of 7 to 13-year old Holstein-Friesian cattle was sliced 3 to 4 mm in thickness and then cut into approximately 2.5 cm square pieces. Two groups of 2 kg each of sliced lean were assigned to two curing treatments: (1) with nitrate and nitrite, and (2) with nitrite only. The meat in (1) was cured in a sweet pickle solution containing 50.0 g salt, 25.0 g sugar, 1.5 g sodium nitrate and 0.5 g sodium nitrite dissolved in 1000 mL water. The resulting salinity of this solution was 22°. The meat in (2) was cured in the same manner except that sodium nitrate was not added to the curing solution. The beef was cured in the appropriate solution for 7 days at 3 $\pm$ 1°C. After curing, the meat was quickly (5 s) washed once in tap water, drained and cooked for 60 min at 15 lb pressure in a Mirromatic pressure cooker. The cooked meat was allowed to cool at room temperature for 30 min, expelled meat juices were allowed to drain and the cooked meat was shredded with a fork into fibers approximately 1 mm in diameter. This study was replicated 4 times with four different animals.

Drying

The shredded meat was dried in a forced air oven regulated to a temperature of 79.4°C (175°F) until the moisture content was between 8 and 12%. The meat was cooled to room temperature and samples for proximate analysis were obtained.

The dried meat in each treatment was packaged in a low moisture (water vapor transmission rate was 0.6 g/100 sq. in./24 h at 100°F at 90% relative humidity),

low oxygen (oxygen transmission rate was 0.35 cc/100 sq. in./24 h at 72°F at 0% relative humidity) transmission rate film (LC Flex 90366 film by Smith Co.). One half of the dried meat in each treatment was vacuum (21 in. Hg) packaged and the other half was packaged tightly in the same type of bag and closed with a Poly bag sealer. The meat was stored for up to 12 weeks at 32° to 33°C.

Analytical Methods

Moisture, crude fat, protein, ash and residual nitrite of the dried beef were determined according to AOAC Procedures (1975) as described by Ockerman (1980). Sugar content was calculated by subtracting the percent of moisture, fat, protein and ash from 100%.

Thiobarbituric acid (TBA) values were determined by the method of Tarladgis *et al.* (1960) as modified by Zipser and Watts (1962).

Water activity was evaluated by placing the dried beef in a Hygroline instrument equipped with a recorder, model SMT.

The pH of the dried beef was determined by blending 10 g of dried beef with 100 mL of distilled water for 1 min and measuring the slurry with a standarized (pH 4 and 7) Beckman Zeromatic pH meter according to the method described by Ockerman (1980).

At 0 and 12-weeks of storage, packages of dried meat from treatments (1) and (2), vacuum and nonvacuum packaged were opened for microbiological examinations. A 20 g sample was removed and mixed in a Stomacher (Model No. 400, Dynatech Laboratory) with 180 mL distilled water for 2 min.

Total aerobic plate counts were made using Tryptone Glucose Extract Agar (Difco), and incubating at 37°C for 48 h. Anaerobic microbial counts were established using Anaerobic Agar (BBL) and incubating at 25°C for 5 days in anaerobic jars containing CO_2.

Salt content was determined using the Dicromat (R) salt analyzer-1000 (Diamond Crystal Salt Co.). For this determination, 20 g dried beef sample was blended with 200 mL of distilled water, filtered through filter paper supplied with the unit and the liquid portion was poured into the reservoir of the analyzer. The filtered solution is exposed to a previously standarized (known salt solutions) electrode and the salt level is digitally displayed on the analyzer.

Sensory Panel Evaluation

Samples of the dried beef were served to each of the six (3 oriental and 3 Americans) trained members of a descriptive attribute panel at 0, 3, 6, 9 and 12 weeks of storage. The panelists evaluated each sample for color, rancid flavor, rancid odor, brittleness and acceptability, using a 10-point scale with 1 representing for each evaluated factor — light in color, not rancid in flavor, not rancid in odor, not brittle and also not an acceptable product and with 10 representing

for each evaluated factor — dark in color, rancid in flavor, rancid in odor, very brittle and also an acceptable product.

Statistical Analysis

The data were analyzed using a factorial experiment in a randomized complete block design (Steel and Torrie 1960).

RESULTS AND DISCUSSION

Moisture, protein, fat, ash, salt and sugar content of dried beef did not differ significantly between treatments (1) and (2) (Table 1). Water activity and pH value were also similar in both the nitrate-nitrite and nitrite cured dried beef.

TABLE 1
PROXIMATE COMPOSITION AND OTHER PROPERTIES OF THE DRIED BEEF AT ZERO STORAGE TIME

PARAMETER	NO_3/NO_2 CURE TREATMENT 1	NO_2 CURE TREATMENT 2	C.V.
Moisture, %	7.76	7.69	5.54
Protein, %	61.03	64.98	3.51
Fat, %	13.02	13.63	9.28
Ash, %	5.14	5.02	4.94
Salt, %	4.14	4.07	5.62
Sugar, %	13.05	8.68	-
a_w	0.38	0.39	2.13
pH	5.99	6.05	0.85

There was no significant variation in the residual nitrite and TBA values obtained in treatments (1) and (2) (Table 2). The residual nitrite was significantly affected by method of packaging and decreased with increased storage. This agrees with the work of Kemp *et al.* (1975) who reported decreased levels of nitrite with increased storage time and also agrees with Woolford and Cassens (1977) who indicated that there was a general dissipation of nitrite with storage time at a decreasing rate due to various reactions of the NO_2 ion with meat tissue.

TABLE 2

RESIDUAL NITRITE (PPM), OXIDATIVE RACIDITY (TBA VALUE), SENSORY PROPERTIES AND ACCEPTABILITY OF DRIED BEEF AS INFLUENCED BY NITRATE, PACKAGING METHOD AND STORAGE TIME

PARAMETER	TREATMENT		PACKAGING METHOD		STORAGE IN WEEKS AT 32-33°C					C.V.
	Nitrate/ Nitrite cure (1)	Nitrite Cure (2)	Vacuum	Non-Vacuum	0	3	6	9	12	
Residual Nitrite	11.7[a]	12.0[a]	12.6[a]	11.1[b]	15.9[a]	13.8[b]	11.5[c]	10.2[d]	7.9[e]	10.4
TBA value	1.5[a]	1.4[a]	1.4[a]	1.6[a]	0.3[e]	1.2[d]	1.6[c]	1.9[b]	2.3[a]	24.7
Color[f]	6.6[a]	6.5[a]	6.7[a]	6.4[a]	7.6[a]	5.9[c]	5.6[c]	6.7[b]	6.9[b]	11.9
Flavor[g]	5.0[a]	4.8[a]	5.1[a]	4.7[b]	2.5[d]	5.1[b]	4.1[c]	6.9[a]	5.8[b]	18.4
Odor[h]	4.5[a]	4.4[a]	4.6[a]	4.4[a]	3.9[b]	4.1[b]	4.3[ab]	4.9[a]	5.0[a]	19.9
Brittleness[i]	8.3[a]	8.3[a]	8.3[a]	8.3[a]	8.4[ab]	8.2[ab]	8.0[b]	8.2[ab]	8.5[a]	5.2
Acceptability[j]	5.9[a]	6.1[a]	5.8[a]	6.2[a]	7.9[a]	5.8[bc]	6.1[b]	5.0[d]	5.3[cd]	14.0

[a-e]means with different superscripts within treatment, packaging method and storage time categories are significantly different at the 5% level.

f = 1=light, 10=dark
g = 1=not rancid, 10=rancid
h = 1= not rancid, 10= rancid
i = 1= not brittle, 10=very brittle
j = 1=not acceptable, 10=acceptable

TBA values were significantly increased with storage time.

The sensory properties and acceptability scores of dried beef are presented in Table 2. Color, rancid flavor, rancid odor, brittleness and overall acceptability were not influenced by the addition of nitrate in the cure. Packaging method also did not significantly affect the color, rancid odor, brittleness and acceptability score. Surprisingly, dried beef which was vacuum packaged was evaluated by the panel as being slightly ($P < .05$) more rancid in flavor than the nonvacuum samples which did not agree in direction with the TBA values which were not significantly different ($P > .05$) between treatments. The sensory properties were also significantly affected by storage. Brittleness scores were essentially similar throughout the storage period.

The overall acceptability scores were significantly ($P < 0.05$) higher (more acceptable) at 0 week storage and significantly decreased on the third week. The scores up to the sixth week were not significantly different from the third week. The results suggest that the product was acceptable up to at least the sixth week.

The pressure cooking technique and drying would be expected to destroy the microbiological population. Counts at 0 week storage would represent postcooking contamination and counts at 12 weeks storage would represent postcooking contamination and survival in the storage environment. At 0 week storage, the total plate counts (Log_{10} values) were 1.71 for the nitrate and nitrite group (Treatment 1) and 1.35 for the nitrite group (Treatment 2). The concentration of sugar (overall mean, 10.87%), low water activity ($a_w = 0.38$) and low moisture content (7.72%) along with the cooking and drying treatment of the dried beef samples probably were responsible for the low level of microorganisms in the samples.

At the twelve week storage period, the total plate counts for the nitrate-nitrite, vacuum and nonvacuum groups were both reduced to 0.50 (log_{10}). The nitrite group had no bacterial growth for the vacuum packaged meat and 1.24 for the nitrite nonvacuum packaged meat.

Anaerobic bacteria was not found in any of the dried beef treatment groups at either the 0 or 12 weeks storage time suggesting that the product was not recontaminated after cooking with these organisms.

SUMMARY

Lean beef from the chuck of 7 to 13 year old cattle was used in this study. Two curing treatments were used and they consisted of both nitrate and nitrite or only nitrite added to the curing brine. The cured meat was cooked under 15 lb of pressure for 60 min, shredded and dried in a forced air oven at a temperature of 79 °C until the moisture content was between 8 and 12%. One half of the dried beef from each curing treatment was vacuum packaged and the other half was tightly packaged and closed with a poly bag sealer. The meat was stored up to 12 weeks at 32-33 °C.

Sensory properties, residual nitrite, TBA values and microbial counts were determined. Under the conditions of this experiment, the dried beef was acceptable up to, at least, the six weeks storage period.

REFERENCES

AOAC. 1975. *Official Methods of Analysis.* 12th ed. Assoc. of Official Analytical Chemists. Washington, D. C.

KEMP, J. D., LANGLOIS, B. E., FOX, J. D. and VARNEY, W. Y. 1975. Effects of curing ingredients and holding temperature on organoleptic and microbiological properties of dry cured sliced ham. J. Food Sci. *40*, 634.

OCKERMAN, H. W. 1980. Quality Control of Post-Mortem Muscle Tissue. Animal Science Dept. The Ohio State University. Columbus, Ohio 43210.

STEEL, R. G. D. and TORRIE, J. H. *Principles and Procedures of Statistics with Reference to Biological Sciences.* 481 p. McGraw-Hill Book Co., New York.

TARLADGIS, B. G., WATTS, B. M. and YOUNATHAN, M. T. 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. J. Amer. Oil Chem. Soc., *37*, 44.

WOOLFORD, G. and CASSENS, R. G. 1977. The fate of sodium nitrite in bacon. J. Food Sci. *42*, 586.

ZIPSER, M. W. and WATTS, B. M. 1962. A modified-thiobarbituric acid (TBA) method for the determination of malonaldehyde in cured meats. Food Technol. *16*, 102.

GAMMA, ELECTRON BEAM AND ULTRAVIOLET RADIATION ON CONTROL OF STORAGE ROTS AND QUALITY OF WALLA WALLA ONIONS

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ABSTRACT

Walla Walla onions were irradiated with doses of 0.1, 0.3, 1.0, 2.0 and 3.0 kGy of gamma rays; 0.1, 1.0, 2.0, 3.0 and 5.0 kGy of electron beams; or 0.44 $\times 10^4$, 1.32 $\times 10^4$, 3.52 $\times 10^4$, 7.33 $\times 10^4$ and 19.1 $\times 10^4$ erg/mm$\pm$ of UV. The onions were stored up to four weeks at 20-25 C. UV irradiated onions exhibited the greatest percentage of marketable onions and reduction in postharvest rots. Sprouting was observed with control, UV and electron beam irradiated onions but not with gamma irradiated onions. Effect of gamma, electron beams and UV on pH, moisture, ascorbic acid and color were not significant. Onions became soft with the high dose of gamma radiation (3.0 kGy). Total sugar content was not affected by UV and electron beam but tended to be greatest at the 1.0 kGy gamma radiation. The effect of the radiation on the onion sensory scores was not clearly indicated except that 3.0 kGy gamma ray irradiated onions had the lowest firmness score.

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INTRODUCTION

Walla Walla sweet onions (*Allium cepa.* L) produced in the State of Washington is a high moisture onion making them susceptible to postharvest rots within 30 days after harvest. Postharvest diseases tend to limit marketing to the East Coast. Marketability of the onions will be greatly enhanced if the shelf-life of the onions can be extended a few more weeks following harvest.

Extensive studies have been conducted during the past thirty years on the effect of ionizing radiation on various fruits and vegetables (Akamine and Moy 1983; Dallyn and Sawyer 1961; Diehl 1983; Kader 1986). Recently, the Food and Drug Administration (FDA) has approved the treatment of fruits and vegetables with gamma irradiation up to 1 kGy (Federal Register 1986). Ultraviolet rays (UV) which are nonionizing radiation have been used extensively in disinfection of equipment, glassware, and air by industries for many years (Fields 1978). The effect of UV on bacteria and fungi such as *Penicilli* and *Aspergilli* has been reported by Kleczkwski (1968). Moy *et al.* (1977) combined UV and gamma radiation for preservation of papaya. Accumulated data has indicated that radiation energy has potential application to extend the shelf-life of fresh fruits and vegetables and could replace fumigants which are often toxic and carcinogenic.

The purpose of this study was to determine the effectiveness of gamma, electron beam and UV irradiation on the control of storage rots and quality of onions.

MATERIALS AND METHODS

Onions

Fresh Walla Walla onions were obtained at Walla Walla, Washington, in July, 1985.

Sources of Radiation

Three types of radiations; UV, electron beam and gamma rays were employed. For UV radiation onions were irradiated to doses of 0.44×10^4, 1.32×10^4, 3.58×10^4, 7.33×10^4 and 19.10×10^4 ergs/mm^2 with a germicidal UV lamp (30 W, G.E.). Onions were placed approximately 10 cm from the surface of the lamp and each onion was rotated four positions facing the lamp. For electron beam, a 2 Mev Van deGraff accelerator was used to irradiate onions to doses of 0.1, 1.0, 2.0, 3.0 and 5.0 kGy. Also, onions were rotated in four positions. The UV and electron beam treatments were carried out at the Battelle Pacific Northwest Laboratories, Richland, Washington. The gamma ray irradiation was carried out in the Cobalt-60 hot cell at the Georgia Institute of Technology at Atlanta, Georgia. The onions were irradiated with doses of 0.1, 0.3, 1.0, 2.0, and 5.0 kGy using a dose rate of 1.37 kGy/h. The radiation energy was deter-

mined from sources UV and electron beam radiation were carried out at room temperature (20-25°C) while gamme radiation was carried out at 25°C. Temperature change in onions was insignificant after irradiation.

Storage

After irradiation, onions were stored at ambient temperatures, 20-25°C and examined periodically for storage rot and sprouting.

Microbial Count

The relative propagate forming units (microbial load) per g of onion was determined by randomly selecting three onions for microbial load at 24 h after radiation. Each onion was weighed and homogenized in a Waring Blendor with sterilized water. The blended onions were diluted 10^{-1} to 10^{-3}, then 0.5 mL was dispensed into culture plates. About 15 to 20 mL of molten potato dextrose agar (Difco) amended with 2.5 μg/mL of streptomycin sulfate and 8 μg/mL of neomycin were poured over the sample and mixed well. The cultures were incubated at 28°C for 3-4 days and the number of colonies was counted. Also the microbial causal agents of rots were identified by examining the rotten onions for microorganisms by a microscope in situ and in vitro. Four onions were picked up at random and sprouting and soundness of onions were determined visually.

Analysis

One week after radiation, moisture and ascorbic acid were determined (AOAC 1980). Sugars were analyzed by a HPLC system (LDC/Milton Roy Rivera Beach, Florida) equipped with a refractomonitor. An amino 5 S column (BioRad) was employed. The solvent system consisted of 75% acetonitrile and 25% water at a flow rate of 1.5 mL/min at 20°C.

An Instron Model 1132 texture meter equipped with a Warner Bratzler's Shear (Instron, Canton, Mass.) was employed to determine texture of tissue. A half inch thickness tissue was cut out from the center portion of the onion tissue and its resistance to shear determined. Color values were determined by a Minolta Chroma meter II (Minolta Corp. Ramsey, NJ) and expressed as L, a and b values.

Sensory Evaluation

Three fresh and cooked onions from each treatment were evaluated for flavor, taste and firmness one week after radiation. Fresh onions were prepared by peeling off the outside skin, and chopping into pieces with a knife and three onions were combined together. Cooked onions were prepared as follows. One cup of chopped onions was cooked with one teaspoon of margarine on a teflon coated skillet for 2 min at the temperature setting of 250°F. A 9-point hedonic scale was employed. Nine represented like extremely and 1 represented dislike ex-

tremely. Students, staff and faculty on the campus of Tuskegee University participated in the test.

Statistics

A standard analysis of variance was performed and Duncan's multiple range tests were employed to determine differences among the means. (Steel and Torrie 1980)

RESULTS AND DISCUSSION

An examination of the spoiled onion tissue and petri dishes revealed the presence of Aspergillus, Penicillum and Erwinia species. In all cases at most dose levels, UV irradiated onions exhibited the most noticeable reduction in postharvest rots and improvement in the marketable and storagelife of Walla Walla Onions (Table 1). Electron beam and gamma irradiated onions appear to be most effective at the lower dose levels in reducing rots. Sprouting was observed with onions irradiated with electron beam, UV and nonirradiated onions. Gamma rays at all doses completely inhibited sprouting. The effectiveness of gamma rays for prevention of sprouting has been reported with other fruits and vegetables (Matsuyama and Umeda 1983).

There was an inverse relationship of the initial microbiel load to the increasing doses of gamma radiation (Table 2). Table 2 also shows that there were no differences between the initial microbial load and the dose levels of UV irradiation and levels of electron beam irradiation in most cases.

Some evidence indicate that gamma rays, X-rays and UV radiation used in certain dosages may stimulate plants. Luckey (1980) reported the effects of low radiation doses on various agricultural crops such as faster germination of seeds, rapid initial growth, greater crop yield and disease resistance. The phenomenon which is referred to as radiation homesis. It is not clear why UV irradiated onions exhibited the most noticeable reduction in postharvest rots in this study, but it was reported previously that irradiation of soybeans and peas with UV induced the formation of phytoalexins (antimicrobial compounds) (Bridge and Klarman 1972), and increased resistance of the plants to Phytophthora megasperms var sojae.

Table 3 shows the composition of irradiated onions. Walla Walls onions contained a high moisture content (91-94%). The effect of radiation on moisture was not evident. The pH of onions was slightly acidic (5.7-6.0). One of the important vitamins in onions is ascorbic acid. The Walla Walla onions contained appreciable quantity of ascorbic acid (Table 3) indicating that this is a good source of ascorbic acid. Ascorbic acid is relatively radio sensitive. Losses of ascorbic acid ranging from 0 to 95% have been reported depending on the commodity, the cultivar, the gamma radiation dose, and the duration and the temperature of storage (Maxie

TABLE 1
GAMMA, ELECTRON BEAM AND ULTRAVIOLET ON POSTHARVEST ROT AND SPROUTING OF WALLA WALLA SWEET ONIONS

Treatment	Percent Sprouted	Percent[a] Marketable Sound	Disease[b] Severity
Gamma (krad)			
300	0	0	3.28
200	0	0	3.50
100	0	25	1.00
30	0	25	1.00
10	0	50	0.40
0 (control)	50	0	1.80
Electron Beam (Krad)			
500	25	0	2.00
300	25	25	1.25
200	25	0	1.25
100	0	50	1.28
10	0	75	0.23
0 (control)	25	25	1.82
Ultraviolet ($ergs/mm^2 \times 10^4$)			
19.10	25	75	0.05
7.33	0	100	0.05
3.58	25	75	0.20
1.32	0	75	0.17
0.44	25	50	0.90
0 (control)	0	25	2.00

[a]Marketable sound = onions that were free of sprouting, irradiation damage and disease severity.
[b]Disease severity scale of 0 to 4; 0 = no infection, 1 = 0.5 to 25% infected, 2 = 25.5 to 50% infected, 3 = 50.5 to 75% infected and 4 = greater than 75% infected.

and Abdel-Kader 1966). In the present short duration study the effect of radiations; gamma ray, electron beam and UV on ascorbic acid was not significant ($P < 0.05$).

Sugar analysis showed that the major sugars in Walla Walla onions were glucose and fructose with sucrose being a minor one. The effects of UV and electron beam on sugar content were not evident probably because UV and electron beam do not penetrate deep into the onion tissue. With gamma radiation, the sugar content increased with dose and reached 6.3% total sugar at 1.0 kGy before declining at the two high doses. Increase in sugar was previously reported by Hayashi and Kawashima (1982), who found that more than 10% sugar was formed in sweet potatoes after gamma irradiation. The decrease in sugar at high doses could be due to the degradation of sugar molecule as a result of high energy radiation. High moisture and relatively high sugar content would invite fungal growth. This could be one reason why Walla Walla onions spoil easily.

TABLE 2
MICROBIAL LOAD DETERMINATION FOR WALLA WALLA ONIONS

Treatment	The Microbial load[b] (PFU)[a] 24 hours after irradiation
Gamma (Krad)	
300	12
200	4
100	$2.8 \times 10^{1}_{2}$
30	$6.9 \times 10^{2}_{3}$
10	$1.0 \times 10^{3}_{3}$
0 (control)	2.2×10^{3}
Electron Beam	
500	$2.0 \times 10^{3}_{2}$
300	$6.6 \times 10^{2}_{3}$
200	$2.0 \times 10^{3}_{1}$
100	$6.7 \times 10^{1}_{2}$
10	$1.8 \times 10^{2}_{3}$
0 (control)	2.7×10^{3}
Ultraviolet (ergs)mm^{2}	
19.1×10^{4}	1.8×10^{4}
7.3×10^{4}	3.6×10^{3}
3.58×10^{4}	1.6×10^{3}
1.3×10^{4}	3.3×10^{3}
0.44×10^{4}	4.6×10^{3}
0 (control)	2.5×10^{3}

[a]Propagage forming unit per gram (PFU)
[b]Microbial load = total fungi and bacteria average of 3 onions.

Color and texture are two important attributes of food quality. The colorimetric meaasurement of L, a and b values showed that "L" values ranged from 68-77, "a" values −2 to −9 and "b" values 3.8 to 7.3 for onions. The effect of radiation on onions was not apparent and difficult to assess because of the great variation among the onions even within the same treatment. Visual observation indicated that the color of the inside tissues appeared white with some pale green color and no apparent difference in color was observed. Some onions irradiated with high dose (3.0 kGy) appeared watery and soft when touched. The texture score was also low ($P < 0.05$) for the onions irradiated to 3.0 kGy gamma rays. Electron beam and UV radiation did not affect the texture of onions (Table 4).

The results of sensory evaluation are summarized in Table 5. Onions, either fresh or cooked, irradiated with low doses gamma radiation, such as 0.3 kGy, received the highest score for taste and flavor. The smallest firmness score was observed with at 3.0 kGy for both cooked and fresh onions. The low firmness score was in agreement with the shear press score as indicated in Table 4. The sensory scores of fresh onions was generally similar to that of cooked onions.

TABLE 3
UV, ELECTRON BEAM AND GAMMA RADIATION ON COMPOSITION OF WALLA WALLA ONIONS

Treatment		Ascorbic acid mg/100g	Glu	Fru %	Suc	Total Sugar
	3.0	8.4[a]	1.57[b]	1.39[a]	0.67[a]	3.64[bc]
Gamma	2.0	10.1[a]	2.51[a]	2.33[ab]	0.52[a]	5.37[ab]
rays	1.0	8.1[a]	2.01[ab]	2.80[a]	0.48[a]	6.30[a]
	0.3	10.1[a]	2.96[a]	2.73[a]	0.56[a]	6.25[a]
kGy	0.1	10.7[a]	2.09[ab]	1.93[ab]	0.36[a]	4.44[b]
	0.0	10.7[a]	1.43[b]	1.30[b]	0.28[a]	3.01[c]
	5.0	6.6[a]	1.66[a]	1.56[a]	0.10[b]	3.26[a]
Elec-	3.0	7.2[a]	1.39[a]	1.25[a]	0.17[a]	2.84[a]
tron	2.0	9.0[a]	1.41[a]	1.39[a]	0.17[a]	2.96[a]
beam	1.0	6.5[a]	1.18[a]	1.10[a]	0.12[ab]	2.36[a]
	0.1	9.4[a]	1.64[a]	1.45[a]	0.10[b]	3.18[a]
kGy	0.0	6.4[a]	1.36[a]	1.28[a]	0.10[b]	2.66[a]
	19.10	7.9[a]	1.58[ab]	1.17[a]	0.20[a]	2.94[a]
UV	7.33	11.7[a]	1.71[a]	1.19[a]	0.10[a]	2.97[a]
	3.58	8.9[a]	1.52[a]	1.01[a]	0.20[a]	2.73[a]
ergx10^4	1.32	8.4[a]	1.23[b]	0.91[a]	0.13[a]	2.20[a]
/mm^2	0.44	7.6[a]	1.20[b]	0.94[a]	0.10[a]	2.20[a]
	0	8.4[a]	1.70[ab]	1.05[a]	0.10[a]	2.76[a]

Means with the same superscript in the same columns are not different at the 5% level.

Flavor and taste scores were not affected by radiation doses but onions irradiated with high doses of gamma radiation received small firmness scores. The results indicate that gamma radiation had no conspicuous effect on flavor and taste but it tended to affect firmness at high dose, i.e. 3.0 kGy.

The sensory scores of both cooked and fresh onions irradiated with electron beam were generally similar and no apparent difference was observed among the onions except that the flavor score of 0.1 kGy onions tended to be large and the flavor and taste scores of fresh onions at 0 krad were small. For UV irradiated

TABLE 4
UV, ELECTRON BEAM AND GAMMA RADIATION ON TEXTURE OF WALLA WALLA ONIONS

Treatment		Texture lb
Gamma Rays kGy	3.0	4.0[b]
	2.0	7.0[a]
	1.0	6.5[a]
	0.3	6.9[a]
	0.1	7.1[a]
	0.0	8.4[a]
Electron Beam kGy	5.0	5.6[a]
	3.0	6.9[a]
	2.0	6.8[a]
	1.0	6.0[a]
	0.1	9.0[a]
	0.0	6.6[a]
UN ergs10^4 /mm^2	19.10	7.4[a]
	7.33	6.0[a]
	3.50	8.0[a]
	1.32	7.2[a]
	0.44	9.1[a]
	0.00	7.1[a]

Means with the same superscript in the same columns are not different at the 5% level.

cooked and fresh onions there was no difference in flavor score. Exceptions were a high taste score for cooked onions irradiated at 1.32 erg $\times$ 10^4/mm^2 and a smaller firmness score for cooked onions irradiated at 19.10 $\times$ 10^4 erg/mm^2. No difference in flavor, taste and firmness scores were observed with raw onions. Based on the sensory scores, the results generally indicated that UV and electron beam and gamma radiation at low doses did not affect acceptability of onions when compared to control. A difficulty of evaluating fresh onions results from pungent odor which sometimes hinder judges from effectively discriminating between onions. Cooking for two minutes reduced pungency greatly, however, pungency still existed and may have created difficulty for making decisions by the judges. In comparing the effect of gamma, electron beam and UV on soundness of onions by visual observation, chemical analysis and sensory evaluation, the results would indicate that the best radiation source may be UV because microbial load was not large. The percentage of marketable onions that were free of storage rots was great. No significant compositional, color and texture, and sensory quality changes were observed with the onions irradiated with UV. The optimum UV doses were in the range of 3.58-7.33 $\times$ 10^4/mm^2 for Walla Walla onions. In addition UV is much more economical and safer to use than gamma

TABLE 5
EFFECT OF UV, ELECTRON BEAM AND GAMMA RADIATION ON SENSORY SCORES OF WALLA WALLA ONIONS

Treatment		Cooked			Fresh		
		Flavor	Taste	Firmness	Flavor	Taste	Firmness
	3.00	6.5^{a}	6.0^{b}	5.6^{c}	5.7^{a}	5.5^{a}	5.5^{b}
Gamma	2.00	6.6^{a}	6.5^{ab}	6.8^{abc}	6.2^{a}	5.9^{a}	6.7^{ab}
kGy	1.00	7.2^{a}	7.1^{ab}	7.0^{ab}	5.5^{a}	5.9^{a}	6.4^{ab}
	0.30	7.3^{a}	7.6^{a}	7.4^{a}	7.3^{a}	7.0^{a}	8.0^{a}
	0.10	6.0^{a}	6.0^{b}	6.2^{abc}	6.3^{a}	6.5^{a}	6.8^{ab}
	0	6.4^{a}	6.6^{ab}	6.6^{abc}	6.5^{a}	7.0^{a}	7.1^{a}
	5.00	5.6^{b}	5.9^{a}	6.7^{a}	6.2^{ab}	6.7^{ab}	7.0^{a}
Electron	3.00	6.7^{ab}	6.7^{a}	6.7^{a}	6.6^{ab}	5.7^{b}	8.6^{a}
beam	2.00	5.6^{b}	6.4^{a}	6.8^{a}	6.5^{ab}	7.0^{a}	7.0^{a}
	1.00	6.7^{ab}	6.6^{a}	6.6^{a}	5.5^{ab}	5.4^{bc}	5.9
kGy	0.10	7.3^{a}	6.8^{a}	6.1^{a}	7.3^{a}	7.0^{a}	7.3^{a}
	0	6.7^{b}	6.4^{a}	7.0^{a}	4.8^{b}	4.9^{c}	6.4^{a}
	19.10	6.4^{a}	6.3^{b}	6.4^{b}	6.4^{a}	6.4^{a}	7.1^{a}
UV	7.33	7.1^{a}	7.5^{a}	7.5^{ab}	7.4^{a}	7.0^{a}	7.1^{a}
$ergx10^{4}$	3.58	7.1^{a}	6.6^{b}	7.0^{ab}	6.5^{a}	6.5^{a}	7.1^{a}
mm^{2}	1.32	7.1^{a}	7.6^{a}	7.5^{a}	7.0^{a}	6.8^{a}	7.3^{a}
	0.44	6.6^{a}	6.4^{b}	6.5^{b}	7.0^{a}	6.8^{a}	7.3^{a}
	0	6.9^{a}	7.0^{ab}	7.1^{ab}	7.2^{a}	7.0^{a}	7.2^{a}

Means with the same superscript in the same column are not different at the 5% level.

and high speed electron beam irradiation. Sprouting may be a problem with the UV irradiated Walla Walla onions. However, sprouting could be controlled by a combination process — radiating onions with low dose of gamma rays (0.1 kGy) and UV. The combination of UV and low dose gamma radiation may be able to extend the life of Walla Walla onions without microbial or sprouting problems.

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REFERENCES

AKAMINE, E. K. and MOY, J. H. 1983. Delay in postharvest ripening and senescence of fruits. In *Preservation of Food by Ionizing Radiation*. (E. S. Josephson and M. S. Peterson, eds.) Vol. 3, pp. 129. CRC Press, Boca Raton, Florida.

AOAC. 1980. *Official Methods of Analysis*. 13th ed. Association of Official Analytical Chemists, Washington, D.C.

BRIDGE, M. A. and KLARMAN, W. L. 1972. Soybean Phytoalexin, hydroxyphaseollin, induced by Ultraviolet irradiation. Phytopathology *63*, 606-609.

DALLYN, S. L. and SAWYER, R. L. 1961. Effect of gamma and fast electron irradiation on storage qualities of onions. Am. Soc. Hort. Sci. *73*, 390-397.

DIEHL, J. F. 1983. Food irradiation. In *Developments in Food Preservation-2*. (S. Thorne, ed.) p. 25. Applied Sciences Publ., London.

FEDERAL REGISTER, April, 1986.

FIELS, M. L. *Fundamentals of Food Microbiology*, AVI Publishing Co., Westport, CT.

HAYSHI, T. and KAWASHIMA, L. 1982. The effect of gamma irradiation on the sucrose content in sweet potato roots and potato tubers. Agric. Biol. Chem. *46*, 1475.

KLEZKOWSKI, A. 1968. Methods of inactivation by ultraviolet radiation. In *Methods in Virology*. (K. Maramorsch and H. Koprowski, eds.) *4*, 93-138.

KADER, A. ADEL. 1986. Potential applications of ionizing radiation in postharvest handling of fresh fruits and vegetables. J. Food Technol. *40*, 117-121.

LUCKEY, T. D. 1980. Horomesis with ionizing radiation. pp. 222, CRC Press, Boca Raton, Florida.

MAXIE, E. C. and ABDEL-KADER, A. S. 1966. Physiology of fruits as related to feasibility of the technology. Adv. Food Res. *15*, 105.

MATSUYAMA, A. and UMEDA, K. 1983. Sprout inhibition in tubers and bulbs. In *Preservation of Food by Ionizing Radiation*, (E. S. Josephson and M. S. Peterson, eds.) Vol. 3, p. 159, CRC Press, Boca Raton, Florida.

MOY, J. H., McELHANDY, T. and MATSUZAKI, C. 1977. Combined treatment of UV and gamma radiation of papaya for decay control. Food Preservation by Irradiation Proceedings at an IAEA, FAO, Who Symposium. IAEA-SM-221/61, Wageningen.

STEEL, R. G. and TORRIE, I. H. 1980. *Principles and Procedures of Statistics*. McGraw Hill Co., New York.

A STUDY OF HISTAMINE PRODUCTION BY VARIOUS WINE BACTERIA IN MODEL SOLUTIONS AND IN WINE[1]

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It is assumed by some studies that histamine is the causative agent of physiological distress experienced by some individuals following ingestion of red wine. Commonly reported symptoms include facial flushing, nasal congestion, and nausea followed by intense headache. White wines are almost never implicated, presumably because red wine vinification methods lead to much higher concentrations of histamine than are found in white wines. However, Lüthi and Schlatter (1983) administered histamine in apple juice and in wine to 27 human subjects and found no significant relation between histamine ingestion and symptoms of distress. Lowenberg *et al.* (1981) suggested that wine alcohol stimulates the liberation of endogenous histamine and that ingested with wine has no effect on plasma histamine levels.

Histamine concentrations reported earlier (Frohlich and Battaglia 1980) in California red wines average about 5 mg/L and white wines less than half that amount. However, a wide range of levels has been reported (Ough 1971; Zee *et al.* 1983), and concentrations in excess of 40 mg/L histamine are not unknown but neither are values of zero or close to zero. Fast, simple, analytical methods for amine determination are not available, but High Performance Liquid Chromatography (HPLC) has offered a variety of approaches. Generally these involve separation and quantitation of derivatives of amines reacted with fluorigenic reagents such as fluorescamine, dimethylamino-1-naphalene sulfonate (dansyl), and orthophthaldialdehyde (OPT). Battaglia and Frohlich (1978) recommend dansyl as the reagent and extract the fluorescent derivative into ethyl acetate

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for HPLC. Buteau *et al.* (1984) studied all three reagents and rejected fluorescamine and dansyl derivatives but found OPT acceptable when extracted into ethyl acetate. All suffer from the production of many unidentified components formed even in the absence of amine. While OPT is probably the reagent of choice, its amine complex is somewhat unstable even after the addition of 2-mercaptoethanol as stabilizer. Any method that does not include extensive sample clean-up to remove amino acids yields so complex a mixture as to obscure quantitation of amines.

Presumably biogenic amines are formed from their parent amino acid by enzymatic decarboxylation. The following study was made to determine the ability of yeasts and bacterial strains to produce histamine from histidine under different fermentation conditions. Red wines, in addition to their special vinification method, differ from white wines in that they are usually aged longer before marketing. They quite often undergo inadvertent or induced bacterial fermentation to convert malic acid to lactic, lowering the acidity and raising pH. Obviously, one might suspect that the bacteria used for this secondary fermentation causes elevated histamine levels in red wines, even though earlier work had shown most wine lactic acid bacteria did not contain histidine decarboxylase (Weiller and Radler 1976).

MATERIALS AND METHODS

Lactic Acid Bacterial Strains Employed

All of the following strains will assimilate L-malic acid. The strains "8014" (Lactobacillus plantarum ATCC 8014) and "8293" (*Lactobacillus mesenteroides* ATCC 8293) were obtained from the American Type Culture Collection. Gratitude is expressed for the following strains: "M 40" (*Lactobacillus casei*) supplied by Professor Radler, University of Mainz; "PSU 1" (*Leuconostoc oenos*) by Professor Beelman, Pennsylvania State University; "OENO" (*Leuconostoc oenos*) by Microlife Corporation; "MCW" (*Leuconostoc* sp.) and "HI" (*Leuconostoc* sp.) by Vinquiry; and "44.40" (*Pediococcus* sp.) by Bio Logicals, Corporation. The remaining strains were isolated in our department from various wines (Pilone *et al.* 1966). All of the above strains except the first three listed are "malolactic" strains; that is, all except the first three convert L-malic acid to L-lactic acid. The strain "44.40" is often classified as *Leuconostoc oenos* (Pilone *et al.* 1966), but in our hands it must be classified as a species of *Pediococcus* (demonstrating homolactic fermentation with dicoccal and tetracoccal morphology).

Sample Clean-Up

A method (Lewis *et al.* 1980) using a weakly cationic exchange resin Bio-Rex 70 (200-400 mesh, Bio-Rad Laboratories) was employed successfully to isolate

brain histamine. After minor modification of solvent elution, the same resin was used to separate amino acids that also react with OPT to obscure the measurement of histamine. The resin was washed with distilled water to remove fines; with 1 *N* NaOH; then water to remove alkali; with 1 *N* HCl; then wash with water until free of acid. Finally, the resin was equilibrated in 0.5 *M* phosphate buffer, pH 7.5, containing 0.1% w/v ethylenediaminetetraacetic acid (EDTA). Columns were prepared by pouring a 3 cm bed of prepared resin into Bio-Rad Econocolumns (0.5 cm I.D. × 10 cm long).

Just prior to use, the column was washed with 5 mL of water containing 0.1% w/v EDTA. A 5 mL experimental sample was adjusted to pH 7.5 with 1 *N* NaOH and applied to the resin. The resin was washed with three consecutive 5 mL volumes of 0.15 *M* acetate buffer, pH 6.5, and these fractions were discarded. After washing the residue with 5 mL water/0.1% EDTA, histamine was eluted with 5 mL 0.2 *N* HCl into a graduated test tube for volume measurement.

Preparation of OPT Derivatives for HPLC

Fifty mg OPT were dissolved in 1.5 mL methanol, 50 μL 2-mercaptoethanol; then 11 mL 0.4 *M* borate buffer, pH 9.5, were added (Umagat *et al.* 1982). The solution was filtered through a 0.45 μm membrane and stored in the dark for 24 h prior to use.

Just before derivatization, 0.55 mL 1 *N* NaOH was added to 1 mL of the resin-treated sample contained in 0.2 *N* HCl. To 20 μL of this mixture were added 100 μL of the OPT reagent; the solution was mixed for 1 min and 100 μL were injected into the Rheodyne injector to fill the 20 μL sample loop. The sample was applied to the HPLC column at exactly 2 min after OPT addition.

Chromatographic Procedure

An IBM Model 9533 Ternary Gradient Liquid Chromatograph equipped with an IBM Model 7125 fluorescence detector (370 nm excitation and 418-700 nm emission filters) and a Rheodyne 7125 syringe loading sample injector with 20 μL sample loop were used for this study. The chromatographic column was an Octadecyl (C18), 4.5 × 250 mm, maintained at 30°C. The isocratic mobile phase, delivered at 1 mL/min, consisted of 50/50 methanol/0.05 *N* acetate buffer, pH 6.50, plus tetrahydrofuran (99:1).

Production of Histamine from Histidine by Lactic Acid Bacteria in a Synthetic Medium

Ten bacterial strains known to assimilate malic acid were added to a synthetic medium. These included the genera *Leuconostoc, Lactobacillus* and *Pediococcus*. The medium contained 3 g/L L-malic acid, 5 g/L yeast extract, 10 g/L D-glucose and salts (Silver and Leighton 1981) with the pH adjusted to 4.30 with

phosphoric acid. Three replicates of each strain with 10 mg/L of added L-histidine and three without were prepared. All bacteria, except *Lactobacillus brevis* which required re-inoculation, grew quite rapidly. After complete fermentation, the samples were centrifuged and the supernatants frozen until analyzed for histamine by HPLC.

Production of Histamine from Histidine by Bacteria in Grape Juice Medium

Red *Vitis vinifera* grape concentrate was diluted with water to 20.6°Brix, pH 3.61 and total acidity of 0.99 g/100 mL expressed as tartaric acid. The juice received 200 mg/L of yeast extract, 200 μL thiamine and 5 mg/L of L-histidine and was then autoclaved. Those samples to which yeast was added for alcoholic fermentation were inoculated with *Saccharomyces cerevisiae* (U.C.D. Enology #522) to provide approximately 10^6 cells/mL and bacteria was added to give 10^7 cells/mL. The progress of malolactic fermentation was monitored by a paper chromatographic procedure described by Kunkee (1968). After completion of alcoholic and bacterial fermentations, samples were frozen until analyzed for histamine. Each test fermentation was conducted in duplicate. Appropriate controls without inoculation consisted of grape juice frozen with and without being autoclaved and with and without added histidine.

The purpose of the grape juice experiments was to study the ability of several malolactic bacteria to produce histamine in grape juice (before, during or after fermentation), the effect of the stage at which bacteria are added, and the effect of temperature of fermentation. The temperature effect was of interest from an earlier observation that a single grape juice inadvertently held above room temperature before yeast inoculation produced 28 mg/L of histamine. A protocol of yeast and malolactic bacteria addition is given in Table 1. The four bacterial strains used were leuconostoc types ML 34, PSU 1, MCW and HI. The first three are commonly used in the winemaking in California and elsewhere.

RESULTS AND CONCLUSIONS

The results of the histamine analyses shown in Table 2 do not indicate that lactic acid bacteria produced significant amounts of histamine from the decarboxylation of histidine in model solutions.

HPLC analysis showed no significant histamine present (less than 0.5 mg/L) in any of the fermented juice samples, including controls. Figure 1 shows a typical chromatogram with the arrow indicating the histamine peak. This was more or less typical of the wines that had undergone malolactic growth and fermentation. Figure 2 gives a wine that had a similar response but was spiked with histamine at 10 mg/L level.

TABLE 1
GRAPE JUICE FERMENTATION WITH FOUR MALOLACTIC LEUCONOSTOC BACTERIA (ML 34, PSU 1, MCW, HI)

Test	Yeast fermentation	Bacteria added A	Bacteria added B	Temperature of fermentation, °C
1	+	+	-	22
2	+	-	+	22
3	-	+	-	22
4	-	+	-	32

A. Bacteria added at beginning of alcoholic fermentation.
B. Bacteria added at completion of alcoholic fermentation.

TABLE 2
HISTAMINE PRODUCED BY LACTIC ACID BACTERIA IN A SYNTHETIC MEDIUM (mg/L)

Bacteria	No histidine	10 mg/L histidine added
Leuconostoc oenos (ML 34)	0.4	0.5
Leuconostoc oenos (OENO)	0.5	0.3
Leuconostoc oenos (PSU 1)	0.2	0.3
Lactobacillus brevis (ML 30)	0.4	0.2
Lactobacillus delbrueckii (CUC 1)	0.6	0.7
Lactobacillus caseii (M 40)	0.2	0.5
Lactobacillus plantarum (ATCC 8014)	0.6	0.4
Lactobacillus mesentroides (ATCC 8293)	0.1	0.4
Pediococcus cerevisiae (CUC 4)	0.3	0.4
Pediococcus sp. (44.40)	0.7	0.7
Uninoculated medium	0.4	0.3

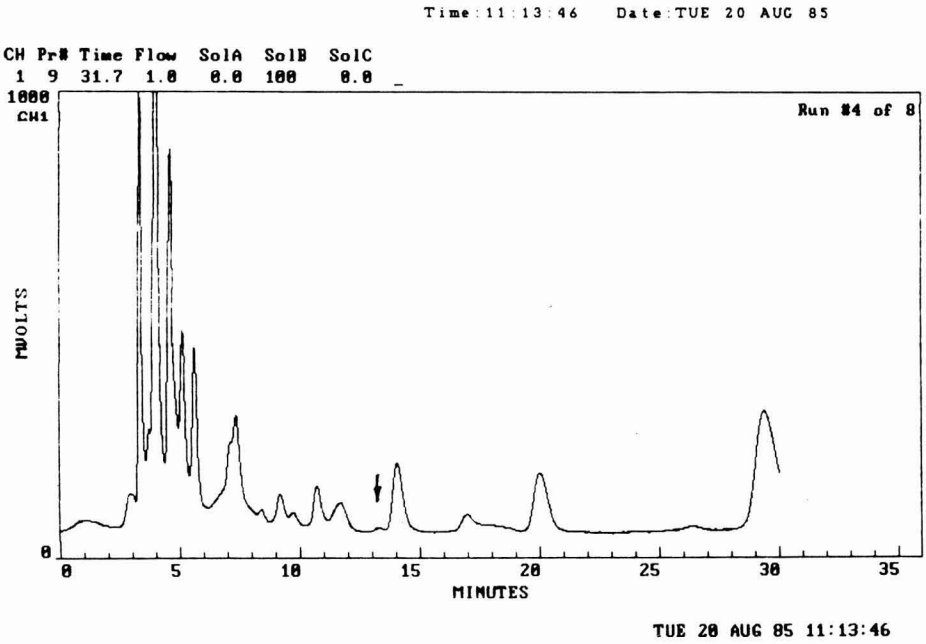

FIG. 1. SAMPLE HPLC CHROMATOGRAM SHOWING A TYPICAL RUN WITH A WINE SAMPLE
Arrow indicates the retention time of histamine.

These results indicate that malolactic fermentation has little to do with the production of histamine during wine making. Our data agree with that of Buteau *et al.* (1984) and of Cilliers (1984). Their data suggest that red wines contain higher histamine levels from the method of vinification and from contamination of yeast and bacterial preparations with nonmalolactic bacteria that may decarboxylate histidine. Our own earlier unpublished work (Ough 1975) also suggested this. Cilliers' data also does not support the hypothesis that histamine is formed by yeast during alcoholic fermentation. All of this evidence means that amino acid decarboxylase enzymes are not well distributed amongst yeasts and more commonly used malolactic bacteria. Previous earlier reports showing mg/L levels in the wines can partially be attributed to contamination and certainly to failure to separate out interfering components.

REFERENCES

BATTAGLIA, R. and FROHLICH, D. 1978. HPLC determination of histamine in wine. J. High Resolut. Chromatogr. Communic. *2*, 100-110.

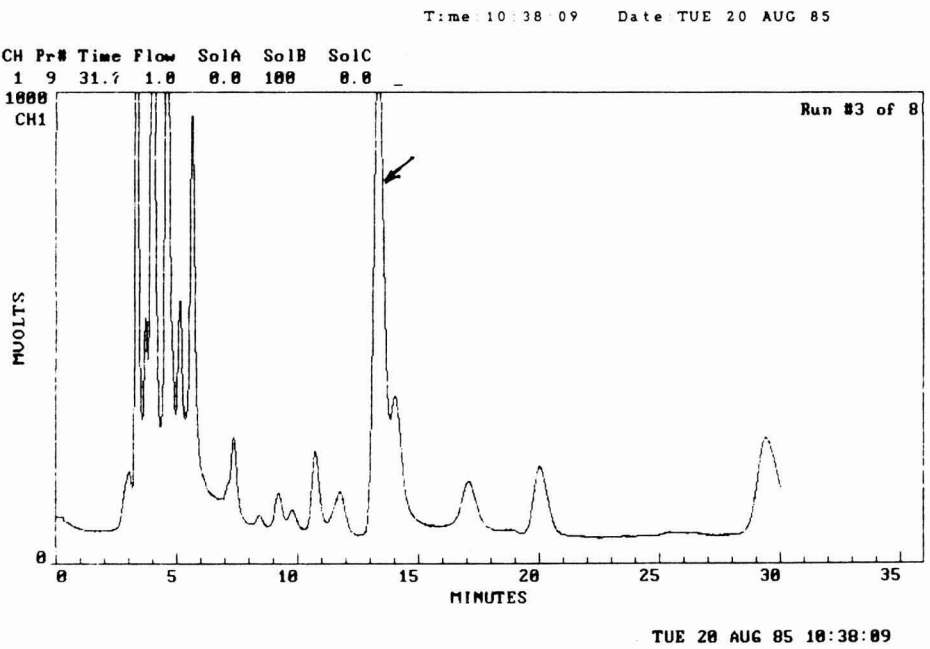

FIG. 2. SAMPLE HPLC CHROMATOGRAM SHOWING A WINE SAMPLE SPIKED WITH 10 mg/L OF HISTAMINE

BUTEAU, C., DUITSCHAEVER, C. L. and ASHTON, G. C. 1984. A study of the biogenesis of amines in a Villard noir wine. Am. J. Enol. Vitic. *35*, 228-236.

CILLIERS, J. D. 1984. Histamine and tyramine content of South African wines. M. S. thesis. University of Stellenbosch.

FROHLICH, D. and BATTAGLIA, R. 1980. HPLC-Analyse von biogenen Aminen in Wein. Mitt. Gebiete Lebensm. Hyg. *71*, 38-44.

KUNKEE, R. E. 1968. Simplified chromatographic procedure for detection of malo-lactic fermentation. Wines and Vines *49*, 23-24.

LEWIS, S. J., FENNESSY, M. R., LASKA, F. J. and TAYLOR, D. A. 1980. A modified method for the isolation and determination of brain histamine using Bio-Rex 70. Agents and Actions *10*, 197-206.

LOWENBERG, D. W., OUGH, C. S., LEPKORSKY, S. and FURUTA, F. F. 1981. The effect of ethanol and wine on the plasma histamine level of chickens and man. Am. J. Enol. Vitic. *32*, 128-131.

LÜTHI, J. and SCHLATTER, C. 1983. Biogenic amines in foods: Effect of histamine, tyramine and phenylethylamine on man. Z. Lebensm.-Unters.-Forsch. *177*, 439-443.

OUGH, C. S. 1971. Measurement of histamine in California wines. J. Agric. Food Chem. *19*, 241-244.

OUGH, C. S. 1975. Unpublished work.

PILONE, G. J., KUNKEE, R. E. and WEBB, A. D. 1966. Chemical characterization of wines fermented with various malo-lactic bacteria. Am. J. Enol. Vitic. *14*, 408-615.

SILVER, J. and LEIGHTON, T. 1981. Control of malolactic fermentation in wine. 2. Isolation and characterization of a new malolactic organism. Am. J. Enol. Vitic. *32*, 64-72.

UMAGAT, H., KUCERA, P. and WEN, L.-F. 1982. Total amino acid analysis using pre-column fluorescence derivatization. J. Chromatogr. *239*, 463-474.

WEILLER, H. G. and RADLER, F. 1976. Uber den Aminosaurestoffwechsel von Milchsaurebakterien aus Wein. Z. Lebens.-Unters.-Forsch. *161*, 259-266.

ZEE, J. A., SIMARD, R. E., HEUREUX, L. L. and TREMBLAY, J. 1983. Biogenic amines in wines. Am. J. Enol. Vitic. *34*, 6-9.

A RESEARCH NOTE: PHYSICAL, CHEMICAL AND SENSORY CHANGES DURING THERMAL PROCESSING OF THREE SPECIES OF CANNED FISH

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ABTRACT

This study was conducted to determine the effect of species and formulation on the physical, chemical and sensory characteristics of catfish, ocean perch and Atlantic pollock during thermal processing. The results show that the changes in pH, thiamin, texture and Hunter 'L' value during canning were different between species. There were no significant differences in the changes in cook-out volume, expressible moisture and TBA values between species. The formulation (water or oil) pack had no effect on the the physical, chemical and sensory tests conducted. The three canned species were judged by ten taste panelists as appetizing in color and flavor and moderate in fish aroma, tenderness, juiciness and overall acceptability.

INTRODUCTION

There has been a steady increase in the per capita consumption of seafood in the United States in recent years. Catfish, a Southern delicacy, is now being served in fastfood chains and is a potential export product (Anon. 1985). New products from underutilized species have also been developed. These include frozen minced fish, seafood chowders, canned minced fish, canned red hake, canned pollock

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and breaded smelts (Baker and Bruce 1982). Despite the introduction of non-traditional and underutilized species commercially, relatively few species are canned in any kind of pack. The commercially important species such as tuna, salmon, herring and sardines still dominate the canned fish market.

Studies have been conducted to determine the marketability of canned pollock (Baker and Bruce 1981). Pollock is an abundant Atlantic species that belongs to the gadoid family. Gadoids contain an enzyme, trimethylamine oxide demethylase, which lowers their refrigerated and frozen shelf-life. Since heat inactivates the enzyme, canning is a logical method of increasing the marketability of this gadoid specie. Freshwater species such as channel catfish have been canned with bones intact, as with canned salmon, to yield a firmer flesh and better appearance (Anon. 1977).

Besides product development, no research work has been conducted on the effect of species and formulation during thermal processing of fish. This research study was conducted to determine the physical, chemical and sensory changes during canning of three species of fish. The species studied were the following: catfish (*Ictalurus punctatus*), a freshwater specie; ocean perch (*Sebastus marinus*), a marine, nongadoid; and Atlantic pollock (*Gadus pollachius*), a marine, gadoid. Two types of pack were prepared, i.e., water pack and oil pack, to determine the effect of product formulation during canning of fish.

MATERIAL AND METHODS

Frozen catfish fillets were obtained from Singleton Corporation (Tampa, Florida) and shipped by air to Cornell University. Ocean perch and pollock fillets were purchased from Foley's (New Bedford, Massachusetts) and shipped on ice to Cornell University. The fillets were frozen and stored at -20 C until use.

Thermal Processing

The frozen fillets were thawed in a walk-in cooler (1.1 C). The thawed fillets were precooked by steaming for ten min for every inch of maximum thickness of each fillet. The precooked fillets were deboned, flaked and handfilled (190 g) into 307 × 113 cans with C-enamel coating (American Can Co.). Five percent water or corn oil (Mazola) and 1% salt were added to the filled can. For catfish, 0.125% ginger extract (Virginia Dare Co.) was added to the water or oil media to mask the mustiness of the fish. The filled cans were vacuum sealed using 43DS closing machine (Continental Can Co.). The canned fish products were processed at 121 C (250 F) at the calculated processing time (F_0 = 10) in a Hydrolock Simulator (WSF Industries). The cans were cooled to an internal temperature of 38 C in the retort and then air-cooled. The processing time (t_B) was calculated using the mathematical method described by Pflug (1982).

Sample Preparation

The contents of the canned sample were drained through a macrofiltration polyethylene mesh (508 μ opening; Spectrum Medical Industries, Inc.) for 10 min. The volume of the drained liquid or cook-out was directly measured in a graduated cylinder. The drained canned fish was referred to as flakes. The fish samples (raw fillets or drained canned flakes) were homogenized in a Waring Blendor for 5 min. The samples for proximate analysis of fat, ash and protein were freeze-dried for 18 h in a Stokes freeze-drier (Model 24; F.J. Stokes Corp.).

Proximate Composition

The raw fillets and drained canned fish flakes were analyzed for moisture, protein, fat and ash in triplicate. The moisture content of a 2 g fresh sample was determined using AOAC (1984) method 24.003. The protein content (Kjeldahl $\times$ 6.25) was determined on a 0.5 g freeze-dried sample based on AOAC (1984) method 2.055. The crude fat was extracted from a 2 g freeze-dried sample using the Goldfisch method (Sebranek 1978). Ash was determined from a freeze-dried 2 g sample following AOAC (1984) method 31.013. The data were expressed on a wet weight basis.

Physical and Chemical Analysis

Physical and chemical analyses were conducted in triplicate on the raw fillets and canned fish.

The pH was determined using a pH meter (Fisher Acumet Model 230A). The percent expressible moisture (%EM) was determined following the method developed by Juaregui (1981). The oxidative rancidity was measured with the thiobarbituric acid (TBA) test of Lemon (1976). The thiamin content was determined using AOAC (1984) method 43.024.

The texture was evaluated using the Instron Universal Testing Machine (Model TTCM; Food Technology Corp.) The Ottawa texturometer extrusion cell (781-30-1) with bottom plate no. 4 was attached to the Instron. The fresh fillet was steamed for 10 min for every inch of maximum thickness prior to the texture test. The steamed fish fillet (190 g) or the drained canned flakes from one can was placed in the cell and extruded using a full scale force of two kiloNewtons (kN) with the crosshead and chart speeds set at 20 cm/min. The maximum force (kN) required to compress, shear and extrude the sample was measured.

The color was measured using the Hunterlab Digital Color Difference Meter (Model D25-2A) with white standard tile C26454.

Sensory Evaluation

A multiple comparison test was conducted to determine the sensory characteristics of the canned fish. Ten semi-trained panelists were presented four

samples of a canned specie, i.e., two samples from each formulation. The panelists were asked to score the samples on a nine-point scale for the following characteristics: color, fish aroma, flavor, juiciness and overall acceptability.

Statistical Analysis

The General Linear Means (GLM) procedure of the Statistical Analysis System (SAS) was used to analyze the data (SAS Institute, Inc. 1982). The results of the physical and chemical tests were analyzed as a two-way analysis of variance (species × formulation) of a completely randomized design. The sensory evaluation data was analyzed as a two-way analysis of variance of a randomized block design using panelists as a block. In both analyses, the Tukey's studentized multiple range test was performed at the 5% level of significance when the F ratio was significant.

RESULTS AND DISCUSSION

Thermal Processing

The calculated processing time ($_B$) was based on one container chosen from six cans (two cans in each of three replicates) with the highest temperature heating response (f_h) for each canned product (Table 1). For all three species, the oil pack had a longer t_B than the water pack since oil is a slower heat conductor than water.

TABLE 1
CALCULATED PROCESSING TIME (t_B) OF CANNED FISH PRODUCTS

Species	Processing time (t_B)(minutes)	
	Canned in 5% water and 1% salt	Canned in 5% oil and 1% salt
Catfish	43	45
Ocean perch	37	40
Pollock	40	43

Proximate Compositon

The proximate composition (Table 2) of the raw fillets agree with the values reported in the literature (Sidwell 1980; Mustafa and Medeiros 1985). The raw

TABLE 2
PROXIMATE COMPOSITION OF RAW AND CANNED FISH

	Species	Proximate composition* Raw fillet	Canned in water**	Canned in oil**
% Moisture	Catfish	77.00 ^{ab}	69.93 ^{cd}	70.48 ^{cd}
	Ocean perch	77.92 ^{ab}	76.79 ^{ab}	73.60 ^{bc}
	Pollock	80.14 ^{a}	70.20 ^{cd}	68.11 ^{d}
% Protein	Catfish	14.02 ^{c}	19.57 ^{c}	20.26 ^{bc}
	Ocean perch	17.93 ^{cd}	19.62 ^{c}	20.60 ^{bc}
	Pollock	17.70 ^{cd}	25.38 ^{a}	24.36 ^{ab}
% Fat	Catfish	7.23 ^{ab}	7.66 ^{a}	7.63 ^{a}
	Ocean perch	2.72 ^{c}	3.81 ^{abc}	3.85 ^{abc}
	Pollock	2.87 ^{c}	4.84 ^{abc}	6.82 ^{ab}
% Ash	Catfish	1.26 ^{cd}	1.63 ^{bcd}	1.64 ^{bcd}
	Ocean perch	1.34 ^{cd}	1.67 ^{abc}	1.80 ^{ab}
	Pollock	1.11 ^{d}	2.18 ^{a}	1.82 ^{ab}

* Within an analysis, means with different superscript letters are significantly different, $p \leq 0.05$, sample size = 3, replicate =2.

**Drained flakes, free of packing liquid.

fillets of the two marine species, pollock and ocean perch, had approximately similar compositions, i.e., 80% moisture content, 18% protein, 3% fat and 1% ash. The raw catfish had a higher fat content (7%) and a lower protein content (14%). Ocean perch and pollock could be classified as a low fatty fish and catfish as a medium fatty fish (Stansby 1962).

There was a significant decrease in moisture content during canning of catfish and pollock which could be attributed to moisture loss during precooking. There was also a significant increase in protein and ash contents during canning of pollock. Canned pollock had the highest protein content among the three species. Except for canned pollock in oil, there was no significant change in the fat content of the three species during canning. This indicated the absorption of fat by the pollock flakes. Other studies (Dudek *et al.* 1982; Hale and Brown 1983; and Chia 1983) have shown that the canning of fish generally results in lower moisture content and a corresponding increase in the proportions of fat, protein and ash contents.

Physical and Chemical Analysis

Table 3 shows the change in pH, % EM, cook-out volume, Hunter 'L', 'a' and 'b', and TBA values during thermal processing of the three fish species.

There was a significant increase in pH during canning of ocean perch and pollock and a significant decrease in pH during canning of catfish in water.

The cook-out volume was not significantly different between species and formulations. The % EM of raw catfish was significantly higher than the % EM of proteins resulting in aggregation changes and decreased water binding capacity of the muscle (Martens *et al.* 1982). The statistical analysis, however, shows that only the increase in % EM during canning of pollock was significant.

The TBA values of the raw and canned fish were very low, hence the samples were not considered rancid. There was no significant difference in the TBA values of the raw and canned products from the three species, except for a decrease in TBA values of canned ocean perch in oil. The oil pack samples had lower TBA values than the water pack samples. This could be due to tocopherol, an anti-oxidant which is present in significant amounts in corn oil (USDA 1979).

Canning caused a significant reduction in thiamin content (Fig. 1). This was expected since thiamin is a heat labile vitamin particularly at pH values higher than 4.0. The thiamin in the flakes and cook-out for both formulations was essentially partitioned between the two phases. This could cause a loss in all of water soluble vitamins in the liquid portion during consumption of canned products if this portion is discarded. A study on canned fruits showed that the concentration of water soluble vitamins is approximately the same in the solid and liquid portions (Brush *et al.* 1944). Fat soluble vitamins can also diffuse from the solid portion to the liquid media for products canned in oil (Bramsnaes 1962).

The results also show that the thiamin retention during canning differed between species. The thiamin content of the flakes and cook-out in decreasing order was catfish > pollock > ocean perch. The % thiamin retention (combined flakes and cook-out) during canning also followed this trend, i.e., $\simeq 65\%$ for catfish, $\simeq 54\%$ for pollock and $\simeq 7\%$ for ocean perch.

The texture force required to compress, shear and extrude the fish in decreasing order was pollock $\simeq$ ocean perch > catfish (Fig. 2). The Ottawa texturometer is based on an empirical concept where the food is deformed and damaged in an arbitrary manner and the resulting force and deformation are assumed to be accurate indicators of food texture. Thus, a meaningful test of the instrument's accuracy is a direct comparison with sensory evaluation data (Voisey 1972). A linear regression of the taste panel scores for tenderness and juiciness as a function of the force measured by the Ottawa texturometer was done to evaluate the predictive value of the instrument. The force measurements were highly correlated with both tenderness ($r = 0.91$) and juiciness ($r = 0.87$) which suggests that the Ottawa texturometer is a good predictor of texture as perceived by a taste panel.

TABLE 3
MEAN VALUES* OF pH, % EXPRESSIBLE MOISTURE, COOK-OUT, TBA VALUE AND HUNTER 'L', 'a' AND 'b' VALUES BEFORE AND AFTER THERMAL PROCESSING OF CANNED FISH

	Species	Raw fillet	Canned in water	Canned in oil
pH**				
	Catfish	6.64^{c}	6.38^{d}	6.56^{d}
	Ocean perch	6.83^{b}	7.15^{a}	7.08^{b}
	Pollock	6.62^{c}	6.90^{b}	6.81^{b}
%Expressible moisture**				
	Catfish	49.82^{a}	52.65^{a}	52.21^{a}
	Ocean perch	38.72^{b}	44.87^{ab}	44.19^{ab}
	Pollock	38.65^{b}	49.62^{a}	49.42^{a}
Cook-out volume (ml)				
	Catfish	-	46^{a}	40^{a}
	Ocean perch	-	40^{a}	31^{a}
	Pollock	-	31^{a}	48^{a}
'L' value**				
	Catfish	55.30 ^{d}	66.50 ^{ab}	67.00 ^{ab}
	Ocean perch	64.67 ^{abc}	61.98 ^{bc}	62.24 ^{bc}
	Pollock	67.80 ^{a}	61.19 ^{c}	63.53 ^{abc}
'a' value**				
	Catfish	-0.83^{a}	0.16^{a}	-0.18^{a}
	Ocean perch	-0.30^{a}	0.68^{a}	0.63^{a}
	Pollock	-1.43^{a}	-0.17^{a}	-0.78^{a}
'b' value**				
	Catfish	10.60 ^{c}	14.34 ^{ab}	13.33 ^{abc}
	Ocean perch	12.37 ^{bc}	15.32 ^{ab}	15.96 ^{a}
	Pollock	12.03 ^{bc}	14.15 ^{ab}	14.64 ^{ab}
TBA (μmole malonaldehyde/100g)				
Flakes**				
	Catfish	0.124 ^{ab}	0.129 ^{ab}	0.068 ^{bc}
	Ocean perch	0.168 ^{a}	0.124 ^{ab}	0.098 ^{bc}
	Pollock	0.084 ^{bc}	0.071 ^{bc}	0.047 ^{c}
Cook-out				
	Catfish	-	0.043 ^{ab}	0.053 ^{a}
	Ocean perch	-	0.061 ^{a}	0.050 ^{ab}
	Pollock	-	0.026 ^{b}	0.045 ^{ab}

* Within an analysis, means with different superscripts are significantly different, $p < 0.05$, sample size = 3, replicate =2.

** For canned products: drained flakes, free of packing liquid.

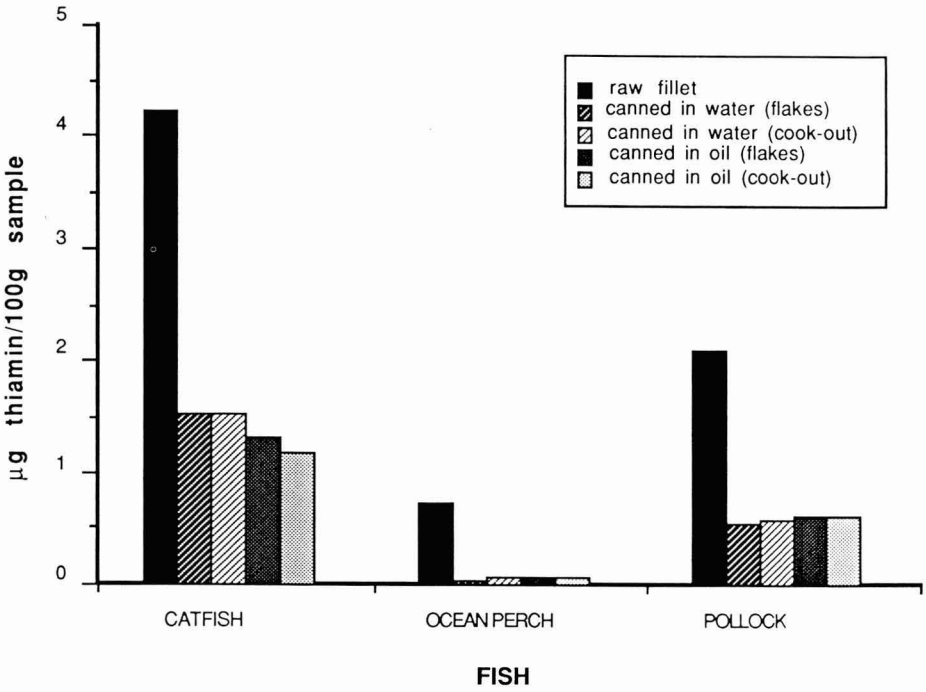

FIG. 1. CHANGE IN THIAMIN CONTENT (µg THIAMIN/100 g) BEFORE AND AFTER CANNING OF CATFISH, OCEAN PERCH AND POLLOCK

Table 3 shows that the higher 'L' values of the raw fillets of ocean perch and pollock indicated a lighter color than the raw fish fillets. There was a significant change in the 'a' values of the three species during canning. The increase in the 'b' values during canning of the three species indicated a deepening of the yellow color. The statistical analysis, however, showed that except for canned catfish in water and ocean perch in oil, there was no significant change in the 'b' values of the raw and canned products.

These results show that the changes in pH, thiamin content, texture and Hunter 'L' value were different between species. The formulation (water or oil packs) of the canned fish products had no effect on the physical and chemical tests conducted.

Sensory Evaluation

The canned fish samples were stored at room temperature for two weeks prior to sensory evaluation to allow time for the salt to equilibrate and the characteristic canned fish flavor to develop. The taste panel scores of the canned fish samples are shown in Table 4.

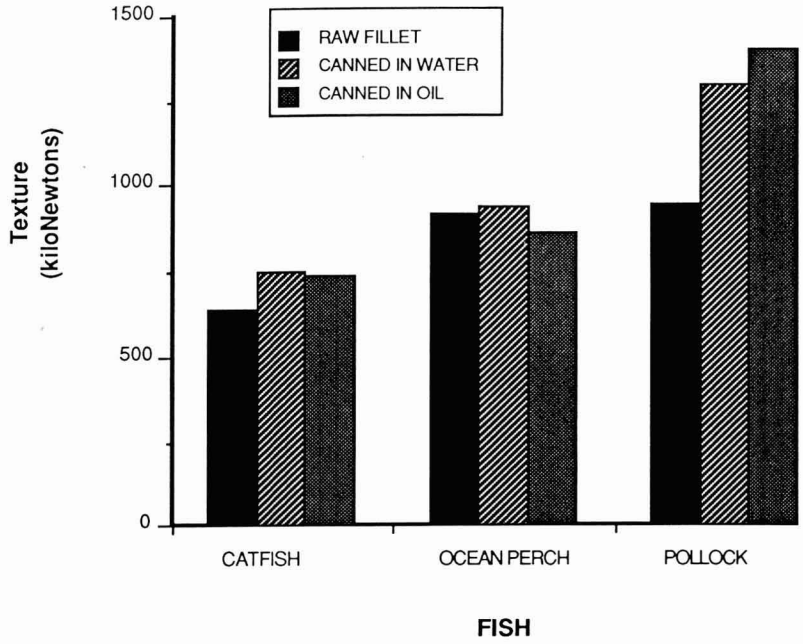

FIG. 2. CHANGE IN TEXTURE (kN) BEFORE AND AFTER CANNING OF CATFISH, OCEAN PERCH AND POLLOCK

TABLE 4
TASTE PANEL SCORES OF CANNED CATFISH, OCEAN PERCH AND POLLOCK USING A NINE-POINT SCALE

	Taste Panel Scores*					
Sensory parameter	Catfish in water	in oil	Ocean Perch in water	in oil	Pollock in water	in oil
Color	7.1^{ab}	7.0^{ab}	6.4^{c}	6.7^{cb}	7.0^{ab}	7.2^{a}
Fish aroma	5.6^{a}	4.8^{a}	5.7^{a}	5.8^{a}	5.8^{a}	5.5^{a}
Flavor	6.3^{a}	6.3^{a}	6.39^{a}	6.4^{a}	6.7^{a}	6.6^{a}
Tenderness	7.1^{a}	6.6^{ab}	6.3^{abc}	6.2^{abc}	5.9^{bc}	5.4^{bc}
Juiciness	6.4^{a}	5.9^{ab}	5.5^{ab}	5.9^{ab}	5.4^{ab}	5.1^{b}
Overall acceptability	6.4^{a}	6.0^{a}	6.5^{a}	6.6^{a}	6.4^{a}	6.0^{a}

* Within a parameter, means with different superscripts are significantly different, $p < 0.05$, sample size = 10.

The color scores of the canned fish samples differed significantly between species but not between formulations. All samples were described as having a moderate fish aroma (4.85-5.85) and an appetizing flavor (6.30-6.75). Canned ocean perch was significantly darker than the two other species. The aroma and flavor scores were not significantly different between species and formulation. The addition of 0.125% ginger extract to the packing media masked the musty flavor and aroma of catfish. The tenderness and juiciness scores differed between species but not between formulation. Although it is not always significant, the trend in tenderness and juiciness scores in decreasing order was: catfish > ocean perch > pollock. All canned fish samples were described as having above moderate overall acceptability (6.00-6.65).

REFERENCES

Anon. 1977. Canned Catfish enters market dominated by salmon and tuna. Food Technol. *31*(7), 57.

Anon. 1985. Catfish are jumpin'. Time December 9, 1985.

AOAC. 1984. *Official Methods of Analysis.* 14th ed. Association of Official Analytical Chemists, Washington, D.C.

BAKER, R. C. and BRUCE, C. 1981. Retail market tests of canned pollack. Development of Products from Underutilized Species of Fish: Booklet 10. New York State Sea Grant Institute, Albany, New York.

BAKER, R. C. and BRUCE, C. 1982. Today's "trash fish" — Tomorrow's bestsellers? FAO Infofish Marketing Digest *5*, 11-15.

BRAMSNAES, F. 1962. The influence of refrigeration and canning on the nutritive value of fish. In *Fish in Nutrition.* (E. Heen and R. Kreuzer, eds.) pp. 153-160, Fishing News Books, London.

BRUSH, M. K., HINMAN, W. F. and HALLIDAY, E. G. 1944. The nutritive value of foods. V. Distribution of water soluble vitamins from solid and liquid portions of canned vegetables and fruits. J. Nutr. *28*(1), 131-140.

DUDEK, J. A., BEERMAN, S. C., BEHL, B. A., ELKINS, E. R., CHIN, H. B. and FARROW, R. P. 1982. *Composition of Selected Seafoods*, National Food Processors' Assoc., Washington, D.C.

JUAREGUI, C. A. 1981. Effect of polyphosphates on the water binding properties of muscle proteins. Ph. D. thesis, Cornell University, Ithaca, New York.

LEMON, D. W. 1975. An improved TBA test for rancidity. New Series Circular No. 51, Fisheries and Marine Services Canada, Halifax, Nova Scotia.

MARTENS, H., STABURSIRK, E. and MARTENS, M. 1982. Texture and colour changes in meat during cooking related to thermal denaturation of muscle proteins. J. Texture Studies *13*, 291-309.

PFLUG, I. J. 1982. *Syllabus for an Introductory Course in the Microbiology and Engineering of Sterilization Processes*, Environmental Sterilization Laboratory, Minneapolis, Minnesota.

SAS, 1982. SAS *User's Guide: Statistics 1982 Edition*, SAS Institute Inc., Cary, North Carolina.

STANSBY, M. E. 1962. Proximate composition of fish. In *Fish in Nutrition* (E. Heen and R. Kreuzer, eds.) pp. 55-60, Fishing News Books, London.

USDA, 1979. *Composition of Foods — Fats and Oils. Raw, Processed Prepared*, Agriculture Handbook No. 8-4. United Stated Department of Agriculture, U.S. Government Printing Office, Washington, D.C.

VOISEY, P. W. 1972. The Ottawa texture measuring system. Can. Inst. Food Sci. Technol. J. *4*(3), 91-102.

F
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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

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