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Kinetics of Osmotic Concentration of Carrot Preserve

[1]U.S. Shivhare, [1]M. Gupta, [1]S. Basu and [2]G.S.V. Raghavan
[1]Department of Chemical Engineering and Technology,
Punjab University, Chandigarh, 160 014 India
[2]Department of Bioresource Engineering, McGill University,
Ste Anne de Bellevue, H9X 3V9, Québec, Canada

Abstract: Carrot is one of the important vegetable grown throughout the world. It is a rich source of β-carotene, a precursor of vitamin A. Carrot is consumed as raw and cooked as well as used for the manufacture of juice, preserve and pickles. The present study was undertaken to manufacture carrot preserve in (i) sucrose syrup (70° Brix), (ii) syrup of 70° Brix prepared using 50:50 sucrose and glucose and (iii) glucose syrup of 51° Brix, respectively at 25°C. Carrots were peeled, cut to approximately 7 cm length, blanched in boiling water for 0.5 h and transferred immediately into sterilized glass jars containing the syrup. The carrot to syrup ratio was held at 1:4. Two batches of each were prepared. In one of the batch, the TSS of syrup was held constant (i.e., 70° Brix or 51° Brix); while in the other, the TSS of the syrup was not regulated. Kinetics of loss of moisture, ascorbic acid, β-carotene, uptake of sugars, TSS and texture of the product was experimentally determined. In addition, sensory evaluation of the product was also carried out. A mathematical model similar to the Page's equation described adequately the temporal variation of moisture, ascorbic acid, β-carotene, uptake of sugars and TSS of carrot during preserve manufacture. Results of the kinetic parameters and sensory scores indicated that carrots should be osmosed in syrup (70° Brix, constant) containing 50:50 glucose and sucrose.

Key words: Carrot quality, osmotic concentration, preserve

INTRODUCTION

Carrot (*Daucus carota*) is one of the most important root vegetables belonging to the family of *Umbrelliferae*, grown extensively in many countries particularly during winter season. Carrots are a rich source of β-carotene, vitamins A, B and C. Among vegetables, carrot is richer in sugar, which is indicated by its sweetness. Carrots are seasonal and perishable in nature and its shelf life can be increased by drying, freezing, canning, pickling[1] as well as manufacture of preserve. Several attempts have been made towards utilization of carrots for the purpose of preparation of soups, beverages, wine, stews, curries, pies, jams and as blending agents[2].

The preserve is prepared by boiling the prepared material in syrup until the concentration of sugar in the material reaches 55-70%[3-4]. The material should retain its form, should be crisp and permeated with the syrup without any noticeable shriveling of the individual pieces. The commercial method of the preserve involves boiling the peeled and dressed carrots, keeping in 40° Brix syrup overnight, then transferring the carrots to 60° Brix syrup and again immersed overnight. These are then finally stored in syrup of about 70° Brix till further use. Preserve making involves osmotic concentration and is an excellent example of intermediate moisture technology. Osmotic concentration of food materials has been a subject of a number of studies[5-10]. Several factors are known to affect the osmotic concentration process, these are: type of osmotic agent used, concentration; temperature and agitation of osmotic solution; ratio of the solution to the food material and physico-chemical properties of the food. Sucrose has been recommended for osmotic concentration of fruits because of its effectiveness, convenience and desired flavor[11]. The rate of mass transfer has been reported to be accelerated with the increase in concentration, temperature and agitation of the solution[11]; however, the optimum concentration and temperature levels are materials specific[12]. Concentration of osmotic solution decreases with the migration of moisture from the food material into the solution. Consequently, higher ratios of solution to sample have been recommended[12]. The effect of different concentration of sugar solution and sample to syrup ratio on the physico-chemical changes as well as sensory attributes of the product during the manufacture of carrot preserve was investigated by Singh *et al*.[13].

The drying of carrots by freezing, hot air and osmotic dehydration has received considerable attention[14-18]. However, little information is available on the use of

Corresponding Author: G.S.V. Raghavan, Department of Bioresource Engineering, McGill University, Ste Anne de Bellevue, H9X 3V9, Québec, Canada

glucose, mixture of glucose and sucrose and sensory and textural properties of the preserve. The present study was therefore undertaken to study the changes in selected physico-chemical, textural and sensory properties during manufacture as well as to determine the quality of carrot preserve at selected ratios of different sugars. The specific objectives of this study were: (i) assessment of the quality of carrot preserve at different sugar solutions and different concentration and (ii) to study the kinetics of carrot preserve manufacture with respect to physico-chemical, textural and sensory properties.

MATERIALS AND METHODS

Fully ripened carrots, procured from the local market, were thoroughly washed in water to remove the adhering impurities. Using stainless steel knife, about an inch of the root and the top respectively were trimmed off. The mid portion was peeled and cut into pieces of approximately 7cm length. The diameter of the pieces ranged between 2.5 and 3.5 cm of mass of about 55 g. The carrot pieces were dipped in water for overnight then blanched for 1 hr in boiling water with 1.35% potash alum that improved the permeability of syrup solution into the carrot. The blanched carrots were pricked manually at same locations with fork to achieve for better diffusion of sugar into it. These prepared samples were transferred into glass jars containing syrup of sucrose (70°B), 50:50 glucose: sucrose (70° Brix) and 100% pure glucose (51° Brix). Sample to syrup ratio was held at 1:4. All the prepared samples were kept in glass jars at 25±1°C.

Analysis for moisture content, total soluble solids, ascorbic acid, β-carotene, total sugars, reducing sugars and non-reducing sugars[19-20] were carried out after 0, 1, 2, 3, 4, 5, 6, 18, 24, 48, 72, 96, 120, 144, 168, 240, 480, 720, 960 and 1200 hrs, respectively. Triplicate samples were taken for each analysis. For each analysis the carrots were rinsed in water and gently wiped with filter paper to remove excess syrup from the surface.

Texture properties were measured by using Texture Analyzer TA-XT Plus (Stable Micro System, UK) with a 5 kg load cell. The maximum compressive strength required to rupture the sample up to 5 mm depth with a rupture test speed of 1mm/s (pre-test speed = 1.5 mm/s; post-test speed = 10 mm/s) on a flat platform using a cylindrical probe (dia 2 mm) was recorded. The hardness was measured in terms of peak force (g).

Sensory evaluation was carried out using nine-point Hedonic scale by a semi trained panel consisting of 10 judges[21]. The sensory panel was selected among the students and faculty members of the department and the evaluation was carried out in the well-equipped sensory evaluation laboratory. Each panelist was asked to evaluate the product and award the scores according to their preferences for appearance, texture, taste, color and overall acceptability.

RESULTS AND DISCUSSION

Kinetics of osmotic concentration was studied with respect to temporal variation of moisture content, ascorbic acid, β-carotene, total soluble solid, reducing sugars, non reducing sugars and total sugars of the carrot preserve at 25°C.

The model: The data revealed that the rate of variation of the selected constituents was exponential in nature; the rate being higher in the beginning but gradually approaching to its equilibrium at later stage. A mathematical equation similar to the Page model was proposed:

$$\left(\frac{C}{C_0}\right) = \exp(\pm kt^n) \qquad (1)$$

Equation 1 is non-linear and could be expressed in a linearized form as:

$$\pm\ln\{C/Co\} = \ln(k) + n\ln(t) \qquad (2)$$

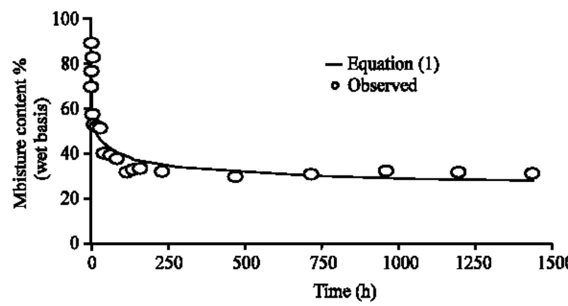

Fig. 1: Kinetics of moisture content loss during osmotic concentration of carrots in 70° Brix sucrose syrup (constant concentration) [sc] at 25°C

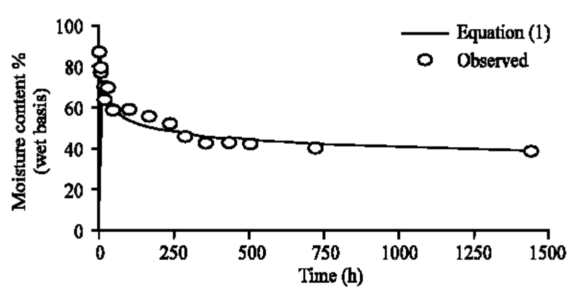

Fig. 2: Kinetics of moisture content loss during osmotic concentration of carrots in 70° Brix sucrose syrup (variable concentration) [sv] at 25°C

Table 1: Coefficients of Equation 1 for various constituents

Constituent	Coefficient	Different sugar syrups: Sucrose (c)	Sucrose (v)	Glucose (c)	Glucose (v)	combination (c)	combination (v)
Moisture content	k	0.1473	0.0365	0.1613	0.1318	0.1441	0.1703
	n	0.1403	0.1280	0.0992	0.0633	0.1400	0.1131
	R^2	0.9334	0.9625	0.9426	0.9799	0.9141	0.9286
	SE	0.0887	0.0505	0.0462	0.0165	0.1010	0.0593
Ascorbic acid	k	0.1368	0.0125	0.0577	0.0350	0.0768	0.2802
	n	0.0935	0.1791	0.1763	0.1978	0.1502	0.1579
	R^2	0.9656	0.9373	0.8169	0.9025	0.9478	0.9856
	SE	0.0334	0.0879	0.1561	0.1215	0.0659	0.0361
β-carotene	k	0.1572	0.2432	0.0098	0.0426	0.0378	0.1503
	n	0.0911	0.2208	0.1113	0.0973	0.1502	0.0891
	R^2	0.8497	0.9333	0.9814	0.6307	0.9310	0.7851
	SE	0.0915	0.1213	0.0253	0.1231	0.0976	0.0865
Reducing Sugar	k	0.8187	2.2181	0.0931	0.3252	0.4020	1.0255
	n	0.2313	0.5063	0.2130	0.1573	0.1774	0.2639
	R^2	0.9182	0.8752	0.7913	0.8074	0.8899	0.9341
	SE	0.1270	0.3957	0.3532	0.1453	0.1470	0.1221
Non reducing sugar	k	0.8220	0.0681	0.0654	0.8094	0.0647	0.0938
	n	0.1484	0.1111	0.2365	0.3753	0.2404	0.1925
	R^2	0.6237	0.6204	0.7856	0.6010	0.6743	0.7110
	SE	0.2171	0.1799	0.1256	0.2430	0.3936	0.2319
Total sugar	k	1.0539	0.3179	0.2059	0.2456	0.6508	0.8398
	n	0.2500	0.1510	0.2319	0.1908	0.1947	0.2831
	R^2	0.7837	0.6575	0.7038	0.7635	0.8518	0.7932
	SE	0.2087	0.2256	0.2846	0.2570	0.1913	0.2731
TSS	k	0.1718	0.9029	0.6160	0.5551	0.5078	0.6424
	n	0.1595	0.2649	0.1947	0.1995	0.1630	0.2002
	R^2	0.9286	0.9139	0.7803	0.6829	0.8597	0.8400
	SE	0.0593	0.2256	0.2846	0.2570	0.1913	0.2731

k = Rate constant, per hour c: constant Brix, n = Dimensionless coefficient. v: variable Brix, R^2 = Coefficient of correlation, %, SE = Standard error, dimensionless

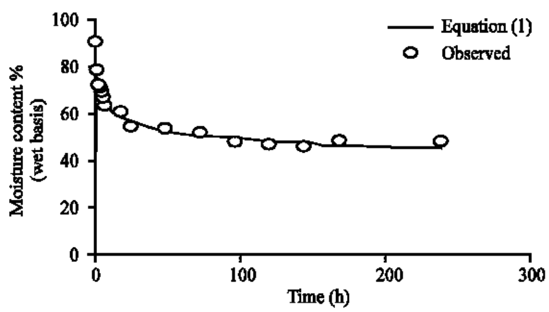

Fig. 3: Kinetics of moisture content loss during osmotic concentration of carrots in 51° Brix sucrose syrup (constant concentration) [sc] at 25°C

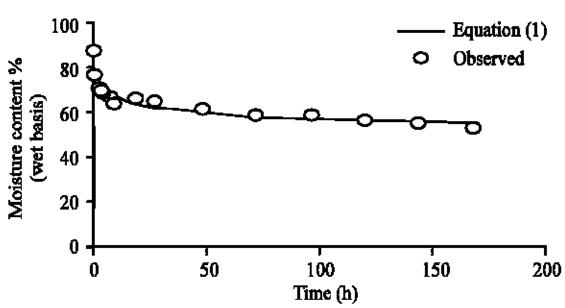

Fig. 4: Kinetics of moisture content loss during osmotic concentration of carrots in 51° Brix sucrose syrup (variable concentration) [gv] at 25°C

Linear regression of Eq. 2 was carried out using the least square technique. The values of the coefficients of regression are given in (Table 1). The variation in moisture content, ascorbic acid, β-carotene, sugars, carotene content and total soluble solids with time at 25°C are shown in (Fig. 1-12). The solid lines in these figures represent the values predicted using Eq. 2. It is evident that the mathematical model, as represented by Eq. 1 describes well the variation of moisture content, ascorbic acid, carotene content, reducing, non-reducing and total sugars and total soluble solids with time at selected sugar solutions of constant and variable concentration. The R^2 values ranged between 0.60 and 0.99 while the standard error values were less than 0.40 in all the cases.

It was observed that carrots, osmosed in syrup (glucose, sucrose, combination of glucose and sucrose) in which the °Brix was not regulated were spoiled within 20 days. It may be due to reduction of °Brix of the syrup with time which eventually facilitated the growth of micro-organisms leading to spoilage of the product. Carrots osmosed in glucose syrup of constant °Brix were also spoiled after 120 days. Further, only two batches: (i) carrots in sucrose syrup (sc) and (ii) carrots in combination of sucrose and glucose (cc) in which °Brix was held constant to its initial level, i.e. 70° Brix were in sound condition even up to 4 months. It can therefore be

Table 2: Sensory data for carrot preserve

Sample	Color	Odor	Taste	Appearance	Texture	Overall acceptability	Remarks
Glucose(c)	7.0	6.5	6.5	7.0	6.7	7.0	spoiled
Glucose(v)	7.5	6.0	6	7.0	6.0	6.0	spoiled
Sucrose(c)	7.2	6.8	7.6	7.2	6.8	7.5	not spoiled
Sucrose v)	8.0	5.7	7.5	7.1	6.0	7.0	spoiled
Combine(c)	7.4	7.0	7.6	7.6	7.2	8.0	most acceptable
Combine v)	7.4	5.0	6.2	6.4	7.0	6.5	spoiled

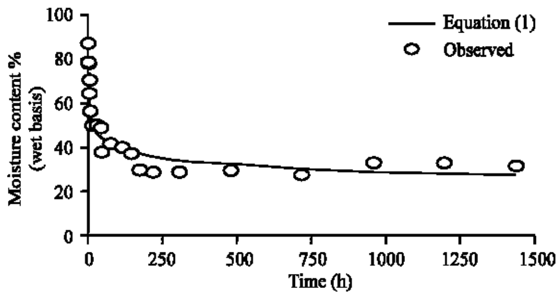

Fig. 5: Kinetics of moisture content loss during osmotic concentration of carrots in 70° Brix of 50:50 glucose and sucrose syrup (constant concentration) [cc] at 25°C

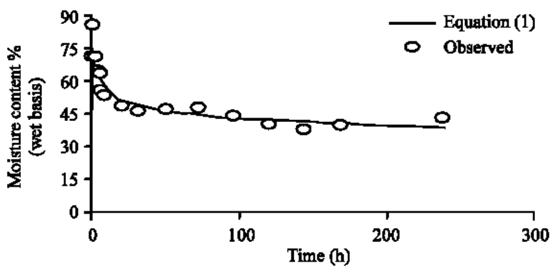

Fig. 6: Kinetics of moisture content loss during osmotic concentration of carrots in 70° Brix of 50:50 glucose and sucrose syrup (variable concentration) [cv] at 25°C

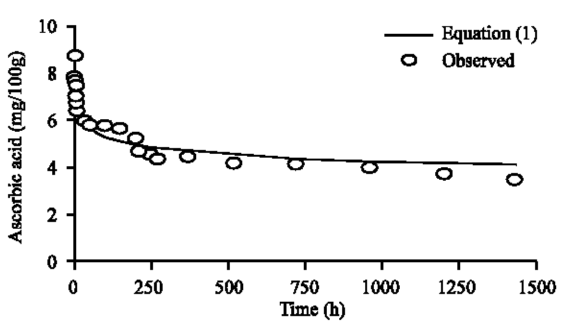

Fig. 7: Kinetics of ascorbic acid loss during osmotic concentration of carrots in 70° Brix sucrose syrup (constant concentration) [sc] at 25°C

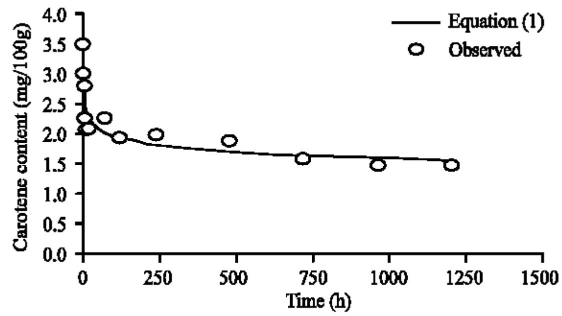

Fig. 8: Kinetics of beta-carotene loss during osmotic concentration of carrots in 70° Brix sucrose syrup (constant concentration) [sc] at 25°C

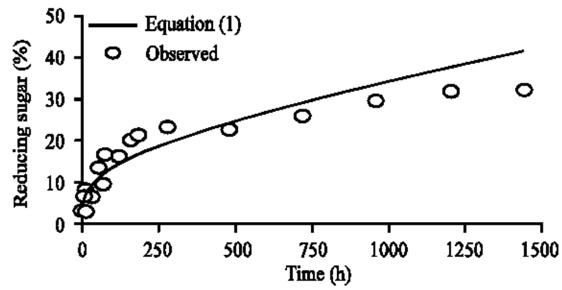

Fig. 9: Kinetics of reducing sugar gain during osmotic concentration of carrots in 70° Brix sucrose syrup (constant concentration) [sc] at 25°C

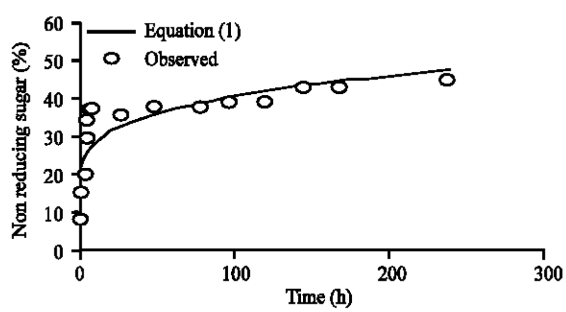

Fig. 10: Kinetics of non reducing sugar gain during osmotic concentration of carrots in 70° Brix sucrose syrup (constant concentration) [sc] at 25°C

inferred that maintenance of 70° Brix of the syrup is essential for manufacture of carrot preserve.

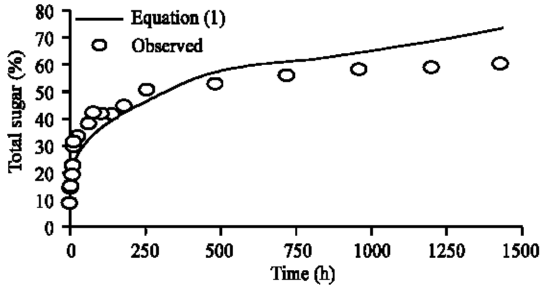

Fig. 11: Kinetics of total sugar gain during osmotic concentration of carrots in 70° Brix sucrose syrup (constant concentration) [sc] at 25°C

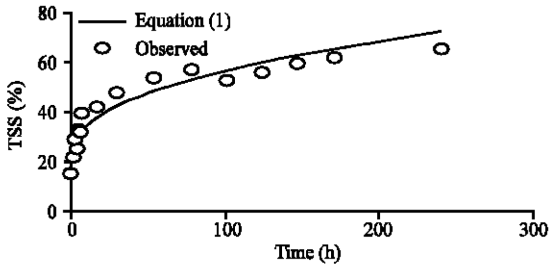

Fig. 12: Kinetics of TSS gain during osmotic concentration of carrots in 70° Brix sucrose syrup (constant concentration) [sc] at 25°C

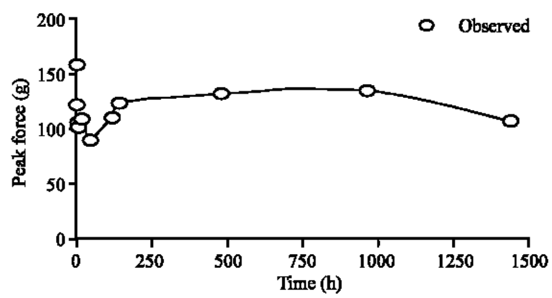

Fig. 13: Temporal various variation of texture during osmotic concentration of carrots in 70° Brix sucrose syrup (constant concentration) [sc] at 25°C

Carrots osmosed in sucrose and mixture of sucrose and glucose of constant °Brix were then compared with respect to retention of β-carotene and ascorbic acid. The loss rate of both ascorbic acid and β-carotene was lower when carrots were osmosed in syrup containing mixture of sucrose and glucose (combination). Carrot preserve manufacture in syrup composed of sucrose and glucose (50:50) (constant 70° Brix) is therefore recommended.

Kinetics of texture properties during osmotic concentration: Variation in force required to rupture osmosed carrots decreased in the beginning and then increased until carrots reached to equilibrium with the surrounding syrup (Fig. 13). Variation in textural behavior was inconsistent and therefore could not be explained. More systematic study devoted to textural behavior of carrots during osmotic concentration is therefore required.

Effect of different sugar syrups on the sensory quality of product: Sensory evaluation of carrot osmosed in selected syrup of both constant and variable °Brix was carried out at 5 day interval. In general, sensory scores increased with time in all the cases. As mentioned earlier, carrots osmosed in syrups of variable °Brix were spoiled within 20 days and sensory scores before the spoilage are reported in (Table 2). Sensory scores of carrot preserve prepared in sucrose and sucrose-glucose syrup of constant °Brix after 960 hrs (40 days) are also included in (Table 2). The data indicated that the sensory scores of the preserve were maximum when carrots were osmosed in sucrose-glucose (combination) syrup.

Based on the sensory evaluation data and rate of loss of ascorbic acid and β-carotene, it may be inferred that carrots should be osmosed in syrup containing 50:50 glucose and sucrose (70° Brix, constant).

CONCLUSION

Results of this study established that spoilage of preserve took place within 20 days when syrup of less than 70° Brix was used. Use of 50:50 sucrose and glucose syrup (constant °Brix) is recommended as it resulted in lower loss of both ascorbic acid and β-carotene of carrots and most acceptable sensory scores during preserve manufacture.

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