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STUDIES ON THE EFFECT OF PARTIAL REPLACEMENT OF SUCROSE BY CORN SYRUP ON THE CHEMICAL AND ORGANOLEPTIC CHARACTERISTICS OF APPLE JAM

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The effects of substitution of corn syrup on the chemical and organoleptic characteristics of apple jam were studied. It was observed that more cooking to higher brix was needed to reach the gelling point, if only sucrose was used. With the increase in corn syrup percentage in jam all the fractions of pectin (soluble-pectin, calcium-pectinate and protopectin) tended to be higher than in the jam prepared with 100 per cent sucrose, but alpha- and beta-cellulose tended to be lower. The effect of different treatments on the pectin fractions and methoxyl content of pectin in jam was found to be inter-related with the storage period, whereas the effect on alpha- and beta-cellulose was independent of storage period.

The organoleptic evaluation data revealed that the judges could not differenciate the colour, texture, odour, taste and flavour between samples. These observations led to the suggestion that jam of equally good quality can be prepared by replacing 20—50% sucrose with high maltose corn syrup, which offers some other technological benefits over sucrose.

INTRODUCTION

Theoretically a jam contains about 68 per cent total soluble solids. The major portion of this percentage comes from sucrose which is added during the preparation of jam. This high amount of sucrose imparts too much sweetness to the product which many consumers do not relish. One possible way to overcome this problem is to replace a portion of sucrose with corn syrup in the production of jams.

Apart from this, there is not enough production of sucrose in Pakistan to meet its other important requirements. Therefore, it would be a useful proposition if some percentage of sucrose can be replaced by corn syrup in the production of jam from fruits. The present studies were conducted to find the optimum level of corn syrup which can replace the sucrose in the making of jam, without affecting its quality characteristics.

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REVIEW OF LITERATURE

Tressler (1940), probably, was the first who suggested that sucrose can be replaced by corn syrup for various jams. According to him such jams had smooth texture, high gloss and improved spreading qualities. Similar views have been expressed by others (Lewis, 1952; Rauch, 1952; Cohee, 1953; Colquhoun, 1961). All these properties are attributed to the presence of dextrines in the corn syrup.

There is, however, a difference of opinion among the different workers as to how much sucrose could be replaced by the corn syrup in jam without affecting its quality. According to Tressler (1940), not more than one fifth of the sucrose amount be replaced by corn syrup. Cohee (1953) and Kooreman (1963) supported this proportion of corn syrup in jam. The same proportion of corn syrup has been recommended for ice cream mix (Coulter *et al.*, 1951), for sweet pickle (Fabian and Pivnicle, 1953) and for canned peaches (Joslyn *et al.*, 1957; Chen and Joslyn, 1967).

On the contrary, Rauch (1952) expressed that substitution of sucrose by corn syrup should approximately be 5 to 15 per cent, while Strachan and Atkinson (1955) claimed that the replacement upto 20 per cent gave better result. Pangborn *et al.* (1959) reported that increasing the corn syrup to higher level caused a decrease in fruit flavour but increased the firmness of the fruit. It appears from these studies that the information provided by different workers is suggestive rather than conclusive.

MATERIALS AND METHODS

Fully ripe apples of Kulu variety were used in this study and were processed according to the procedure given below :

Pulp Extraction: Healthy apples were washed with potable water to remove the dirt and dust and to minimize the microbial load, cut into small pieces (without peeling and coring), cooked for 15 minutes after the addition of water (8 oz per lb. of fruit) and then passed through the tomato pulper.

Jam Making: The pH value of the pulp was adjusted to 3.3 by the addition of citric acid (pH was measured by Beckman pH meter) and then divided into 6 lots of equal weight. The pulp and sugar were mixed in the ratio of 50 parts each (1:1 w/w). Six samples of jam were prepared by taking 5 lbs. of fruit pulp to each 5 lbs. of sugar or sugar plus corn syrup. The percentage of sucrose and corn syrup used in different sample is shown in Table 1.

TABLE 1. *The proportion of sucrose and corn syrup in different jams*

Sample No.	Sucrose	Corn Syrup
1	100%	—
2	80%	20%
3	75%	25%
4	70%	30%
5	60%	40%
6	50%	50%

High maltose corn syrup of 45 Baume was used for replacement purpose.

Analytical Methods. The methoxyl content and different fractions of pectin and cellulose were determined according to the procedures described in an earlier communication by Khan and Asghar (1971). Brix of the jam was determined, using Abbes refractometer as described by A.O.A.C. (1960). The pH value was recorded by using Beckman pH meter. The apple jam was evaluated organoleptically after a storage period of 60 days for colour, texture, odour, taste and flavour by scoring method as described by Krum (1955). The data were subjected to two-way analysis of variance model (Snedecor, 1966) to partition the effect of different variables, considered in this study and the significance of difference between means was examined by Duncan's multiple range test.

RESULTS AND DISCUSSION

The data on different physical and chemical characteristics of jam are shown in Tables 2 and 3.

Total Soluble Solids (Brix) and pH Values. It can be seen from the data in Table 2 that in the case of jam prepared with 100% sucrose the gelling point reached at 219 F, the total soluble solids (Brix) being 71.5%, whereas with 40% corn syrup substituted jams the gelling point reached at lower temperature (216 F), brix being 68.5%. The substitution by corn syrup beyond 30%, however, caused no further reduction in gelling temperature. These results suggest that other conditions being constant, more cooking to higher birx is needed to reach the gelling point if only sucrose is used in jam making.

However, by substitution of corn syrup, the jams can be prepared at lower degree of brix. Naturally this will increase the yield of jam per pound of the fruit used and save the cooking time.

The difference in the degree of brix at which gelling took place in different samples might be due to slight difference in pH value of the samples. The sample which contained more than 25% corn syrup acquired slightly higher pH (3.15), than the samples which contained only sucrose, or, upto 25% of corn syrup (3.10). As the rigidity of the structure in jam is governed by the pH value, the optimum being 3.2 (Hinton, 1940; Bluementhal, 1942; Oliver, 1950; Smock and Neubert, 1950; Jacobs, 1951; Rauch, 1952; Duckworth, 1966; Desrosier, 1970), the pH value of the apple pulp (4.1) was adjusted to 3.3 by the addition of citric acid (it was experienced that the pH of the prepared jam decreased by 0.1 to 0.2 units on cooking). It has been reported by Oliver (1950) that the pH value determines the amount of total soluble solids required to reach the gelling point and the present results supported his findings.

Generally speaking, with respects to total soluble solids all the samples of jams were within British Standard Requirements (Rauch, 1952), but they were somewhat higher than that of American Standard (Prescott and Proctor, 1937; Bluementhal, 1947; Smock and Neubert, 1950; Jacobs, 1951; Cruess, 1958; Desrosier, 1970).

Pectin Fractions. Table 2 shows that the water-soluble pectin, calcium pectinate and protopectin varied between 0.45 to 0.55%, 0.25 to 0.29% and 0.40 to 0.50% (per cent AGA) respectively in jam. The statistical analysis of the data indicates a significant effect of substitution of corn syrup on these fractions ($P<0.01$). The amount of the first two fractions tended to increase with the increase in corn syrup percentage, while the last fraction increased in jams having upto 40% corn syrup, beyond that it declined.

During storage period of 60 days (Table 2 and 3), there was a 3.5 to 5.5 per cent increase in water-soluble fraction, whereas the amount of calcium pectinate and protopectin decreased in different jams ($P<0.01$). The significant first-order interaction, treatments × storage, in all these cases suggests that the changes in these fractions were interrelated to both the storage and treatments ($P<0.05$). The maximum decrease (6.8%) in calcium pectinate was observed in jam prepared with 100% sucrose. Minimum 5% decrease in protopectin occurred in jam with 30% corn syrup, while the change was high on either sides of this concentration.

TABLE 2. *Effect of corn syrup substitution on certain physico-chemical characteristics of apple jam*

Components	*Mean values at zero days storage*						Statistical significance
	T1	T2	T3	T4	T5	T6	
Soluble solids % (Brix)	71.5	70.0	69.0	68.5	68.5	68.5	
pH value	3.10	3.10	3.10	3.15	3.15	3.15	
Jelling point (°F)	219	218	217	216	216	216	
Total pectin (% AGA)	0.90	0.97	0.99	1.02	1.07	1.05	
1. Water-soluble (% AGA)	0.453	0.482	0.495	0.520	0.544	0.553	T ($P<0.01$); Sx = 0.005
2. Ammonium-oxalate-soluble	0.250	0.255	0.258	0.259	0.273	0.290	T ($P<0.01$); Sx = 0.001
3. Sodium-hydroxide-soluble	0.200	0.233	0.236	0.242	0.252	0.209	T ($P<0.01$); Sx = 0.001
Methoxyl content (% of total pectin)	6.09	4.80	4.38	2.8	6.03	6.13	T ($P<0.01$); Sx = 0.0291
Total cellulose (%)	0.81	0.79	0.78	0.77	0.76	0.76	
1. Alpha-cellulose (%)	0.773	0.749	0.741	0.736	0.730	0.728	T ($P<0.01$); Sx = 0.0009
2. Beta-cellulose (%)	0.039	0.038	0.037	0.036	0.035	0.035	

T=variation due to treatment. For other abbreviations refer to foot-note in table 3.

TABLE 3. *Effect of corn syrup substitution and storage on certain physico-chemical chasacteristics of apple jam*

Components	*Mean values at 60 days storage*						Statistical significance
	T1	T2	T3	T4	T5	T6	
Soluble solids % (Brix)	71.5	71.0	69.0	68.5	68.5	68.5	
pH value	3.10	3.10	3.10	3.15	3.15	3.15	
Total pectin (% AGA)	0.89	0.97	0.99	1.03	1.06	1.04	
1. Water-soluble %	0.488	0.501	0.520	0.540	0.563	0.580	S ($P<0.01$); Sx=0.0008; S×T ($P<0.05$)
2. Ammonium-oxalate soluble %	0.233	0.252	0.268	0.259	0.265	0.280	S ($P<0.01$); Sx=0.0006; S x T ($P<0.05$)
3. Sodium-hydroxide-soluble %	0.171	0.212	0.216	0.230	0.236	0.188	S ($P<0.01$); Sx=0.0006; S x T ($P<0.01$)
Methoxyl content (% of total pectin)	5.66	4.45	4.10	2.72	5.94	5.96	S ($P<0.01$); Sx=0.016; S x T ($P<0.05$)
Total cellulose %	0.81	0.79	0.78	0.77	0.76	0.76	
1. Alpha-cellulose %	0.774	0.750	0.741	0.736	0.730	0.730	S (N.S); S x T (N.S)
2. Beta-cellulose %	0.039	0.038	0.038	0.037	0.035	0.035	S (N.S); S x T (N.S)

T1=100% sucrose-jam; T2=80% sucrose+20% corn syrup-jam; T3=75% sucrose+25% corn syrup-jam; T4=70% sucrose+30% corn syrup-jam; T5=60% sucrose+40% corn syrup-jam; T6=50% sucrose+50% corn syrup-jam; S=variation due to storage; Sx=Standard error; S×T=Storage and treatment interaction; N.S.=non-significant

The decrease in sodium hydroxide-soluble and ammonium oxalate-soluble pectin, and increase in water-soluble pectin in jam during storage agreed with the findings of Appleman and Conard (1927), Hsu *et al.* (1965), Kanujoso and Luh (1967), Sattar and Rehman (1967), Haq and Rehman (1968), Haider (1970), Arif (1971) and Mustafa (1971) who reported similar trend in different processed fruit products. The decrease in ammonium oxalate-soluble pectin in jam during storage was at variance with the observations of Rafique (1966), Ahmed and Rehman (1968) and Karim (1969), who observed an increase in ammonium oxalate-soluble pectin in different fruit products during storage.

Alpha- and Beta-cellulose. In freshly prepared jam α– and β–cellulose (on per cent fresh weight basis) varied between 0.73 to 0.77% and 0.035 to 0.039% respectively (Table 2). Both these fractions tended to decrease with the increase in corn syrup percentage in jam ($P<0.01$). The linear trend from T1 to T6 indicates that the decline in the values of alpha and beta fractions was inversely related to the amount of corn syrup in jam. However, during storage period of 60 days, their amount remained almost constant (Table 2 and 3). This is also apparent from non-significant first-order interaction, treatment × storage ($P>0.05$), which suggests that the effect of treatments was independent of storage.

Methoxyl Content of the Pectin: The data on methoxyl content of fresh and stored jam are given in Tables 2 and 3 respectively. In fresh jam the average values ranged from 2.888 to 6.129%. The statistical analysis of the data indicated that the substitution of corn syrup in jams significantly affected the methoxyl content of the pectin ($P<0.01$). With the increase in corn syrup percentage from 20% to 30% in jam, the per cent methoxyl content tended to decrease (as compared to jam with 100% sucrose). But there was a tendency to increase with further increase in per cent corn syrup.

Data in tables 2 and 3 reveal that the methoxyl content of the pectin further decreased significantly after 60 days of storage period ($P<0.01$) and the decrease ranged between 1.4 to 7.1% in different jams. The significant first-order interaction, treatments × storage, revealed that the effect of storage was not independent of treatments ($P<0.05$). The maximum decrease occurred in jam with 40% corn syrup followed by 50%, while in the remaining jams the decrease varied within 6 to 7%. The overall mean values of methoxyl content fell in order 2.802, 4.238, 4.621, 5.877, 5.988 and 6.042 for T4, T3, T2, T1, T5 and T6 respectively. Comparison between the means revealed that jam with 50% and 40% corn syrup were not different ($P>0.05$), rest of the samples were different significantly.

It is generally accepted that methoxyl content governs the jelly formation (Ripa, 1937), although Myers and Bake (1926) believed that the jellies of desirable firmness may be made with pectinic acid of wide range of methoxyl content. They rather claimed that jelly formation tend to increase with the decrease in methoxyl content to about 8%. The present study partly supported the concept of Myers and Baker and it further suggested that the jelly of desired firmness can be made even with pectin having 2 to 6% methoxyl content.

Organoleptic Evaluation: The average score for colour, texture, odour, taste and flavour are given in Table 4. The analysis of variance of data for each parameter suggested that the colour, texture, odour, taste and flavour were not affected by treatments. Again, the significant variation between judges ($P>0.01$) were indicative of the fact that the judges were not unanimous in their opinion in most of the cases, except in evaluating the taste and texture, where they have shown a unanimous opinion that the taste and texture were not affected by the treatments.

Although the scores for texture were not significantly different between samples, the score for corn syrup substituted jam tended to be higher than for the jam prepared with sucrose only. This trend is understandable in the light of the role of different ingredients in the formation of jam. Since the poly-hydroxy compounds like sugar, form bridges between pectin molecules and stabilize the structure by means of large number of hydrogen bondings (Kertesz, 1951), it is very likely that the corn syrup which contains 20% tri- and tetrasaccharides (besides dextrose 11% and maltose 35%) may have contributed in forming more bridges between pectin molecules.

These results reveal that jam of good quality can be prepared by replacing sucrose with high maltose corn syrup which has many advantages over sucrose. It was suggested earlier by Tressler (1940), Meeker (1950), Lewis (1952), Rauch (1952), Cohee (1953), Pangborn *et al.*, (1959), Colquhoun (1961) and Kooreman (1963) that corn syrup can subsitute 5 to 25% of sucrose in jam. Contrary to their opinion, the present study indicates that sucrose can be replaced by high maltose corn syrup from 20 to 50% without affecting the quality characteristics of the jam.

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TABLE 4. *Average score for quality characteristics of jam prepared by different levels of corn syrup substitution*

Quality parameters	Mean score						Statistical significance
	T1	T2	T3	T4	T5	T6	
Colour	4.8	5.6	4.6	5.4	5.6	5.3	J ($P<0.01$); Sx=0.45; T (N.S)
Texture	5.0	5.3	5.4	5.1	5.4	5.4	J (N.S); T (N.S)
Odour	4.8	5.3	5.4	5.0	4.8	4.8	J ($P<0.01$); Sx=0.15; T (N.S)
Taste	5.1	6.0	5.6	5.1	5.0	4.7	J (N.S); T (N.S)
Flavour	4.7	5.1	5.0	5.0	3.6	4.6	J ($P<0.01$); Sx=0.25; T (N.S)

J=variation due to judges; T=variation due to treatment; Sx=standard error For other abbreciations, refer to foot-note table 3.

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