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MOISTURE SORPTION ISOTHERMS AND TEXTURAL CHARACTERISTICS OF APPLE BARS[1]

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ABSTRACT

Apple bars produced from dehydrated Granny Smith apple were examined for their moisture sorption isotherms and texture indices. The desorption equilibrium moisture content was higher than the adsorption moisture content, due to hysteresis effect. The moisture content of apple bar at 0.6 water activity which was considered to be a limit for microbial growth was 21 g H_2O 100^{-1} g dry matter (21% db) on adsorption isotherm. The effect of temperature shift on sorption isotherms showed that in the range of ERH examined, the quantity of adsorbed water at a given relative humidity increased as temperature decreased. The examination of texture index showed that at moisture content of 15 g 100^{-1} solid, the texture hardness was 2.5 kg cm^{-2}, which is considered to be a suitable hardness. The effect of added oil with 1.5% lecithin as an emulsifier softened the apple bar texture, so that with 6% soya bean oil and 1.5% lecithin the texture hardness decreased from 2.6 to 1.1 kg cm^{-2}. The compression of dried apple to produce apple bar had a remarkable effect on reduction in volume. The compression ratio varied from 2.80 to 3.05 depending on moisture content of the apple bar.

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جذب رطوبت همدما و خصوصیات بافتی فروت بار سیب

رستم فرجی هارمی و رابرت استیل
به ترتیب استادیار بخش صنایع غذائی و علوم تغذیه دانشکده کشاورزی دانشگاه شیراز و پژوهشگر ارشد CSIRO استرالیا.

چکیده

فروت بار سیب تولید شده از سیب خشک (گرانی اسمیت) جهت جذب رطوبت همدما و شاخص‌های بافت آن مورد آزمایش قرار گرفت. مقدار رطوبت متعادل دفعی از مقدار رطوبت متعادل جذبی آن به علت پس‌ماند گی بالاتر بود. مقدار رطوبت فروت‌بار سیب در فعالیت آبی ۰/۶ که بالاترین حد جهت پایدار بودن محصول از نظر میکروبیولوژیکی تلقی می‌شود، مساوی ۲۱ گرم بر ۱۰۰ گرم ماده خشک مشخص گردید. بررسی تغییرات دما روی جذب رطوبت همدما نشان داد که در دامنه ERH آزمایش شده، مقدار آب جذب شده در یک رطوبت نسبی معین با کاهش دما افزایش یافت. بررسی شاخص‌های بافت نشان داد که با کاهش رطوبت سفتی بافت افزایش می‌یابد و در رطوبت ۱۵ گرم بر ۱۰۰ گرم ماده خشک سفتی بافت ۲/۵ کیلوگرم بر سانتیمتر مربع می‌باشد. افزودن روغن با ۱/۵ درصد لسیتین به عنوان امولسیون کننده، فروت‌بار را نرمتر کرد، بطوری که با افزودن ۶ درصد روغن سویا و ۱/۵ درصد لسیتین سفتی بافت از ۲/۶ به ۱/۱ کیلوگرم بر سانتیمتر مربع کاهش یافت. فشردن سیب خشک شده بمنظور تولید فروت‌بار اثر قابل ملاحظه‌ای روی کاهش حجم آن داشت. نسبت فشرد گی بسته به مقدار رطوبت از ۲/۸۰ تا ۳/۰۵ متغیر بود.

INTRODUCTION

Fruit bar is a product made from dehydrated fruit of selected moisture content, in a way in which the dried fruit is properly ground and thoroughly mixed with other formulated ingredients and forming into bar.

One of the outstanding advantages of fruit in the form of bars is that they provide highly concentrated nutritional value in compact and convenient forms (4). The average dietary fiber of fruit bars is considered to be high, since fruit such as apple, apricot, pear and peach contain 1.6, 1.9, 3.3 and 2.1 percent dietary fiber respectively (5). Based on this analysis, these fruit bars at a moisture content of up to 15% should contain 8.5, 10.8, 12.75 and 11.9 percent dietary fiber, respectively.

Fruit bars can be stored for considerable period of time without spoilage, especially when the moisture content is sufficiently low to prevent growth of microorganisms in the compact fruit bar (4).

Many causes of postharvest spoilage can be eliminated by moisture limitation of the fruit. Below a certain moisture content, molds, yeasts and bacteria cannot grow to spoil the product (10).

Drying of fruit is usually practiced to some extent in Iran. There are considerable fruit drying industries the products of which mostly include sun-dried fruit such as raisins, apricots, prunes and to some extent other fruits (3). However, there are great potentials for growing apple drying industries in which the dried fruit can be converted to other dehydrated fruit products such as fruit bars.

The drying of fruit to make bars offers a convenient method of marketing fruit that would be either unacceptable or in excess for fresh market.

The magnitude of postharvest losses of fruit is estimated at 25-50% in developing countries depending on the type of commodities (6). Accordingly, these losses emphasize the need for developing processes which can reduce the wastage of fruit in Iran.

One of the problems encountered with fruit bars is that when they are compacted by application of pressure in the form of bars, if the moisture content is as low as is desirable for stability, the fruit bars become so hard that they are difficult to be eaten directly without rehydration. On the other hand, if the moisture is left in the compact fruit bars to permit direct eating of the bars without any difficulty, the fruit bars may be unstable on long-term storage. Further, they may be very difficult to form because of the extrusion of fruit pulp from the mold during compression in forming the bars.

The aim of this investigation was to determine the effect of moisture content on different characteristics of apple bar, including moisture sroption isotherms, texture firmness and bulk density. The effect of vegetable oil on texture softness of apple bar was also studied.

MATERIALS AND METHODS

Granny Smith Apple was purchased in the dehydrated form, containing SO_2, with a moisture content of approximately 28% on the dry matter basis from a major wholesale warehouse in Sydney, in 20 kg plastic bags packed in cartons. Further dehydration of the product was conducted in a cabinet dehydrator at 60° C to obtain different selected levels of moisture content (Tables 1 to 5). Fruit bars were made from dried fruit of different selected moisture contents using a Kenwood blender/mincer equipped with a specially made extruder. Moisture content was examined by weighing a 5-10 g sample of the fruit bar into tared aluminium moisture dishes containing sand and small stirring rods. Five to ten ml of 95% ethanol was added and the sample was stirred into the sand to make a uniform mixture. The mixture was brought to near dryness (1-2% moisture content) in an oven at 60° C and then dried at 60° C under high vacuum for 24 hr and reweighed. Moisture content was determined by difference in weights (2). Duplicate determinations were made on each equilibrium moisture content.

Desorption isotherm was prepared by using the hygroscopic detector liquid technique (9) in which after the samples were equilibrated over-night, the refractive index of the liquid detector was measured, and by using a table (9) the corresponding desorption isotherm was determined. Duplicate determinations were made on each sample.

Adsorption isotherm was determined by placing dehydrated samples in moisture dishes within desiccators containing a saturated salt solution giving a constant relative humidity (8). Constant temperatures were maintained by placing the desiccators in a controlled environment chamber. Samples were weighed twice a week until there was no weight loss or gain. Duplicate determinations were made on each adsorption isotherm.

Sorption isotherms were examined over the range of 1-28% moisture content on dry matter basis.

In order to measure the effect of temperature shift on the moisture sorption isotherm, the samples were stored in a room having a temperature of 25, 35 or 45° C for 24 hr to reach the equilibrium with the head space and then they were examined for their equilibrium relative humidity (1).

Texture examination was carried out on a Instron Universal Testing Apparatus (Model No. 1122) with a 500 kg cell. The samples were penetrated five times in different places to 50% of initial thickness at speed of 2 cm min^{-1} with a cylindrical 0.8 cm diameter flattened punch.

Results were expressed as (1) hardness, which is the mean of maximum for 5 penetrations converted to kg cm^{-2}, (2) toughness, which is the mean of work (kg. cm) expanded for 50% penetration (4).

Bulk density was measured by dividing the weight of the product (dried apple or apple bar) by its respective volume to yield gram per cubic centimeter (4). Compression ratio was determined by dividing the volume of the dried fruit by its respective bar volume.

The effect of oil on textural characteristic of apple bar was determined by adding different amounts of soya bean oil having 1.5% lecithin as emulsifier to the dried fruit. The apple rings were air dried to a moiture content of 15% db then spread out in a pan and spray-coated as uniformly as possible over the surface of the rings until a level of 1.5% lecithin with selected amount of oil by weight was obtained. The rings coated with the lecithin and oil were used to make bars.

RESULTS AND DISCUSSION

Fig. 1 shows the desorption and adsorption isotherms of apple bar at 25° C. As it can be observed the desorption equilibrium moisture content is higher than the adsorption moisture content (hysteresis effect). That is, the water activity corresponding to a given equilibrium moisture content is lower along the desorption than the adsorption branch. The effect of this hysteresis is important on chemical and microbiological deterioration. The greater water activity imparted by the food on adsorption promotes greater activity of microorganism.

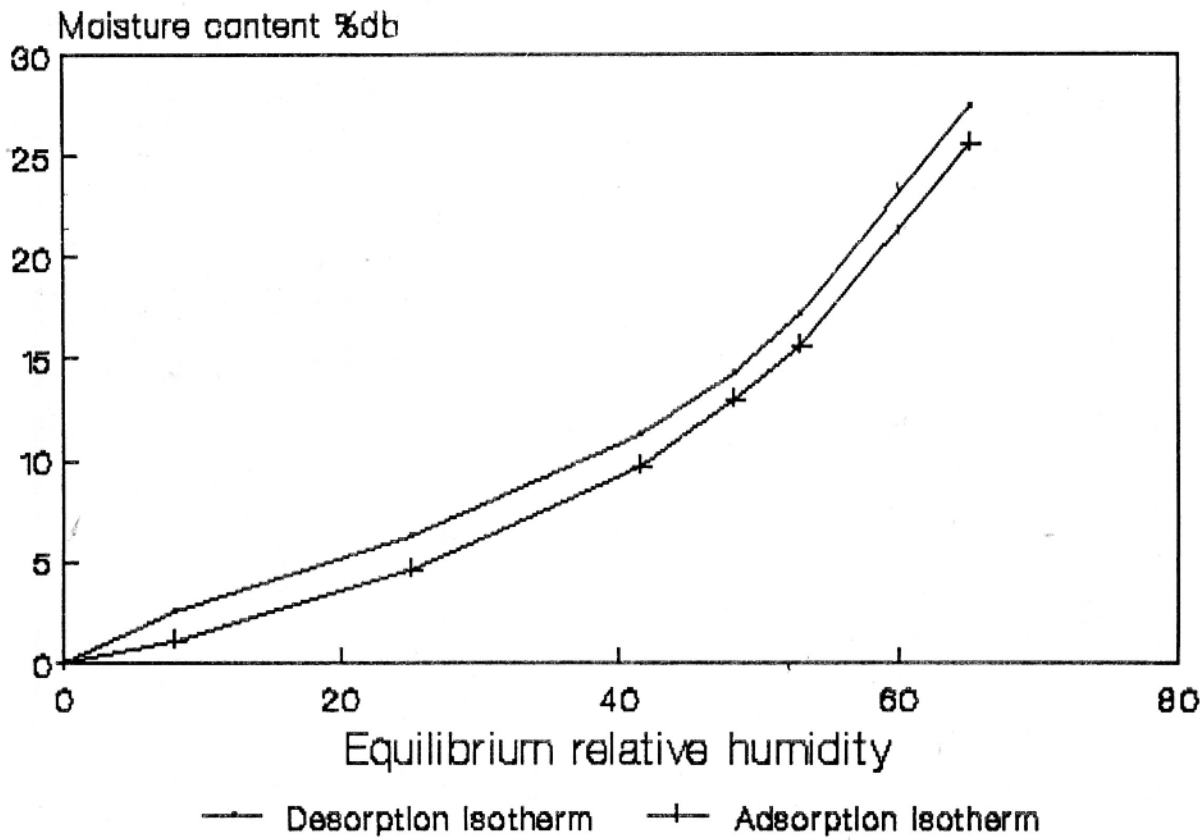

Fig. 1. Desorption and adsorption isotherms of apple bars at 25°C.

The study of temperature shift on adsorption and desorption isotherms of apple bar (Figs 2 and 3) shows that this factor has some effect on the isotherms (Tables 1 and 2). However, it can be noted that at low and intermediate water activities (the ranges studied in this investigation, Tables 1 and 2), the quantity of adsorbed water at a given water activity increases as the temperature decreases. This indicates that at low and intermediate relative humidities apple bar is less hygroscopic with increase in temperature. Consequently in an atmosphere of constant relative humidity it can adsorb more moisture at lower temperatures. This behavior may be due to amorphous solid state of sugars present in the product (7).

Table 1. Desorption isotherms of apple bar at 25, 35 and 45°C.

Water activity	Moisture content % db		
	25°C	35°C	45°C
0.08	2.5	2.5	2.5
0.25	6.3	6.0	5.9
0.41	11.3	11.2	11.0
0.48	14.3	14.0	13.8
0.53	17.2	17.0	17.0
0.65	27.4	27.2	27.0

Table 2. Adsorption isotherms of apple bar at 25, 35 and 45°C.

Water activity	Moisture content % db		
	25°C	35°C	45°C
0.11	1.5	1.5	1.3
0.22	3.5	3.5	3.7
0.33	6.6	6.4	6.3
0.43	10.5	10.0	10.0
0.53	15.6	15.3	15.0
0.73	34.0	33.5	33.6

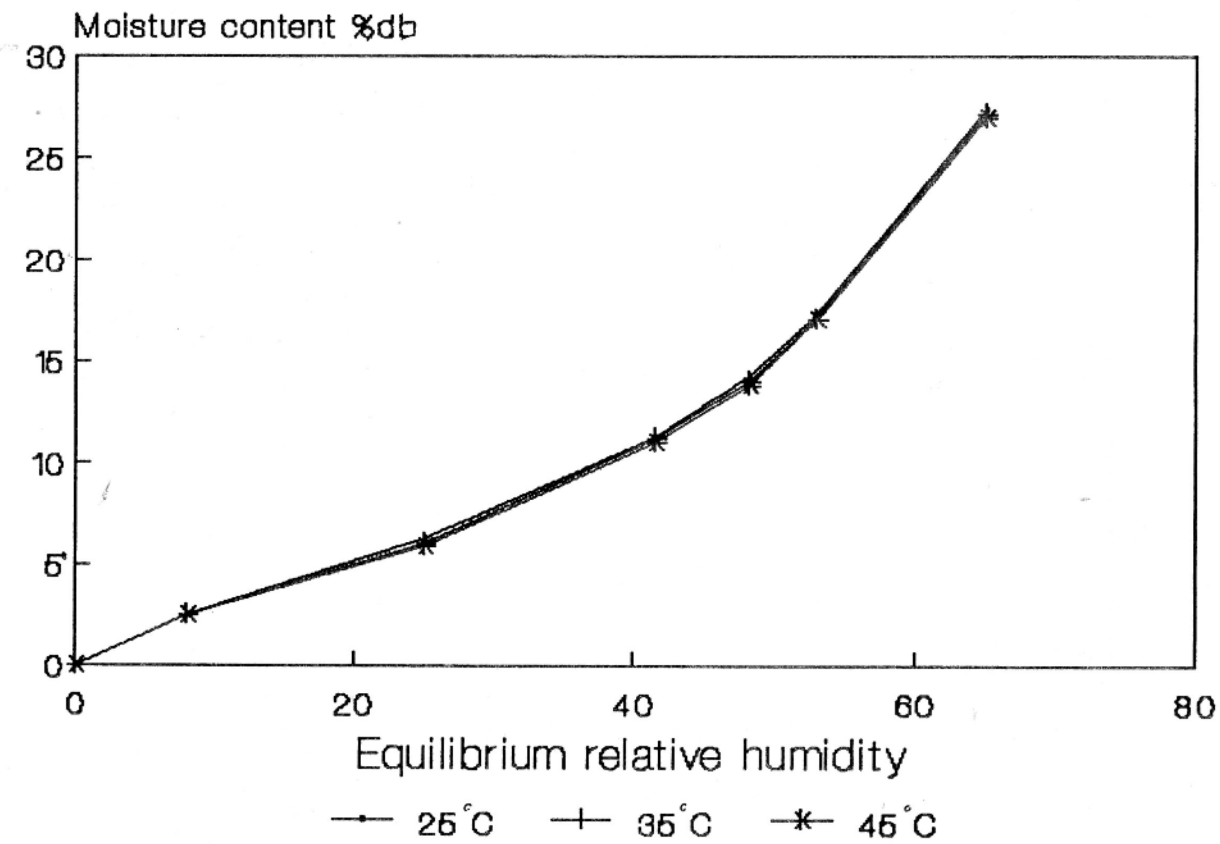

Fig. 2. Desorption isotherms of apple bars at 25, 35 and 45°C.

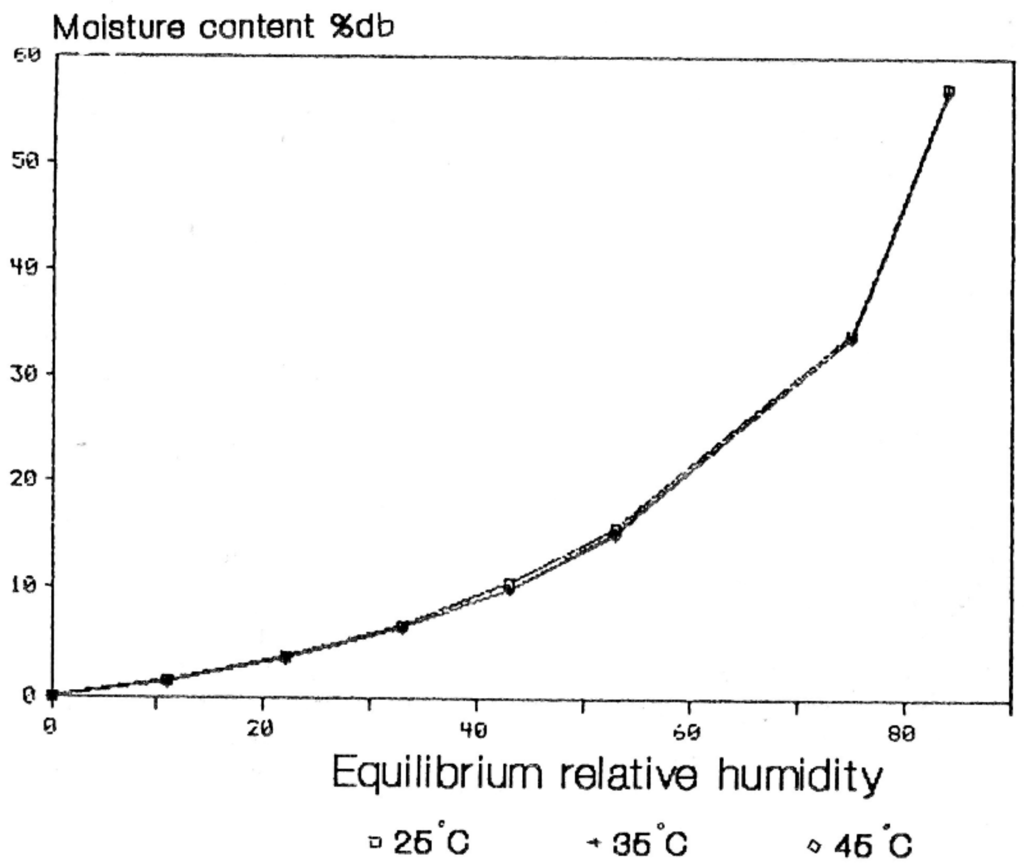

Fig. 3. Adsorption isotherm of apple bars at 25, 35 and 45°C.

The results of texture index examined by Instron is shown in Fig. 4. This figure indicates that the hardness of apple bar has a linear relationship with moisture content up to about 15% db, and then as the moisture content decreases, there is a remarkable increase in texture hardness, and considerable increase in toughness as well.

Although standards for fruit bar texture have not yet been established, the best quality of fruit bar texture attributes could be considered as those which provide an optimum hardness suitable for both forming and eating. However, a number of studies have convincingly shown that the moisture content of dried or semidried foods plays an important role in determining the texture(10).

In this investigation the texture index value of 2.5 (Table 3) for hardness which is considered to have an optimum hardness in terms of eating and forming of apple bar, corresponds to a moisture content of 15% db.

Table 3. Textural characteristics and moisture content of apple bar.

Moisture content % db	Hardness kg cm^{-2}	Toughness kg. cm
7.5	33.4	5.8
9.0	16.6	3.9
11.0	6.9	1.9
15.0	2.5	0.7
19.0	1.6	0.4
25.0	1.0	0.3
28.0	0.9	0.2

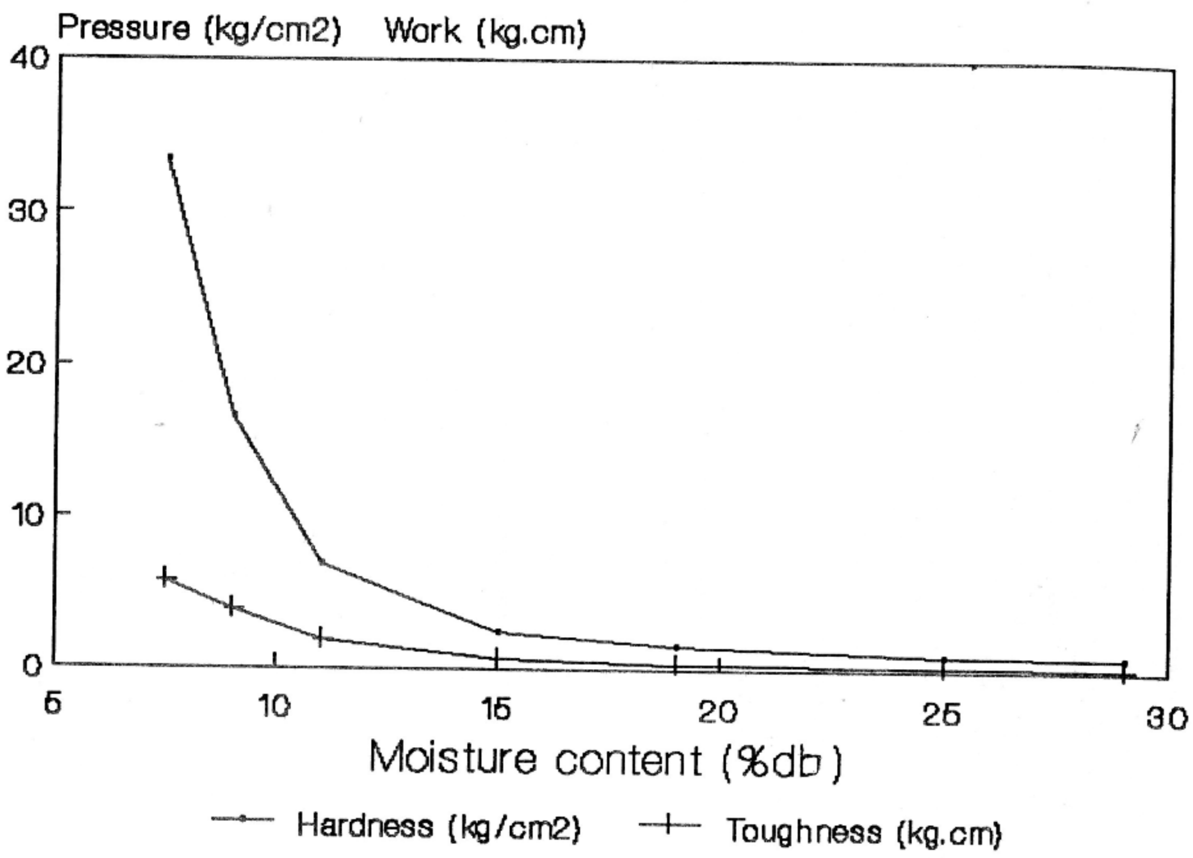

Fig. 4. Textural characteristic of apple bar as a function of moisture content.

According to the adsorption isotherm of apple bars, this moisture content produces a water activity of about 0.52 (Table 2) which is below the limit (0.6) for microbial growth. This water activity corresponds to a moisture content of 21% db for adsorption isotherm.

The effects of added lecithin as an emulsifier and different levels of soya oil are shown in Table 4. The results show that 1.5% added lecithin softened the texture of apple bar from 2.5 to 2.3 kg cm^{-2} as well as the toughness from 0.7 to 0.6 kg.cm. Further reduction in both characteristics was observed by added oil. Both characteristics had almost linear and direct relationship to the different levels of added oil (Fig. 5).

Table 4. Effect of oil on textural characteristics of apple bar (1.5 % lecithin added as emulsifier.)

% Oil added	% Lecithin added	Hardness kg cm^{-2}	Toughness kg. cm
0.0	0.0	2.5	0.7
0.0	1.5	2.3	0.6
1.5	1.5	2.1	0.5
3.5	1.5	1.7	0.4
4.5	1.5	1.4	0.4
6.0	1.5	1.1	0.3

The results of bulk density and compression ratio of different apple bars containing different levels of moisture content are shown in Table 5.

Table 5. Bulk density and compression ratio of apple bar containing different levels of moisture content.

Moisture content % db	Bulk density of dried apple, g cm^{-3}	Bulk density of apple bar, g cm^{-3}	Compression ratio
6.0	0.38	1.15	3.02
8.0	0.38	1.16	3.05
15.0	0.40	1.20	3.00
25.0	0.44	1.23	2.80
29.0	0.45	1.26	2.80

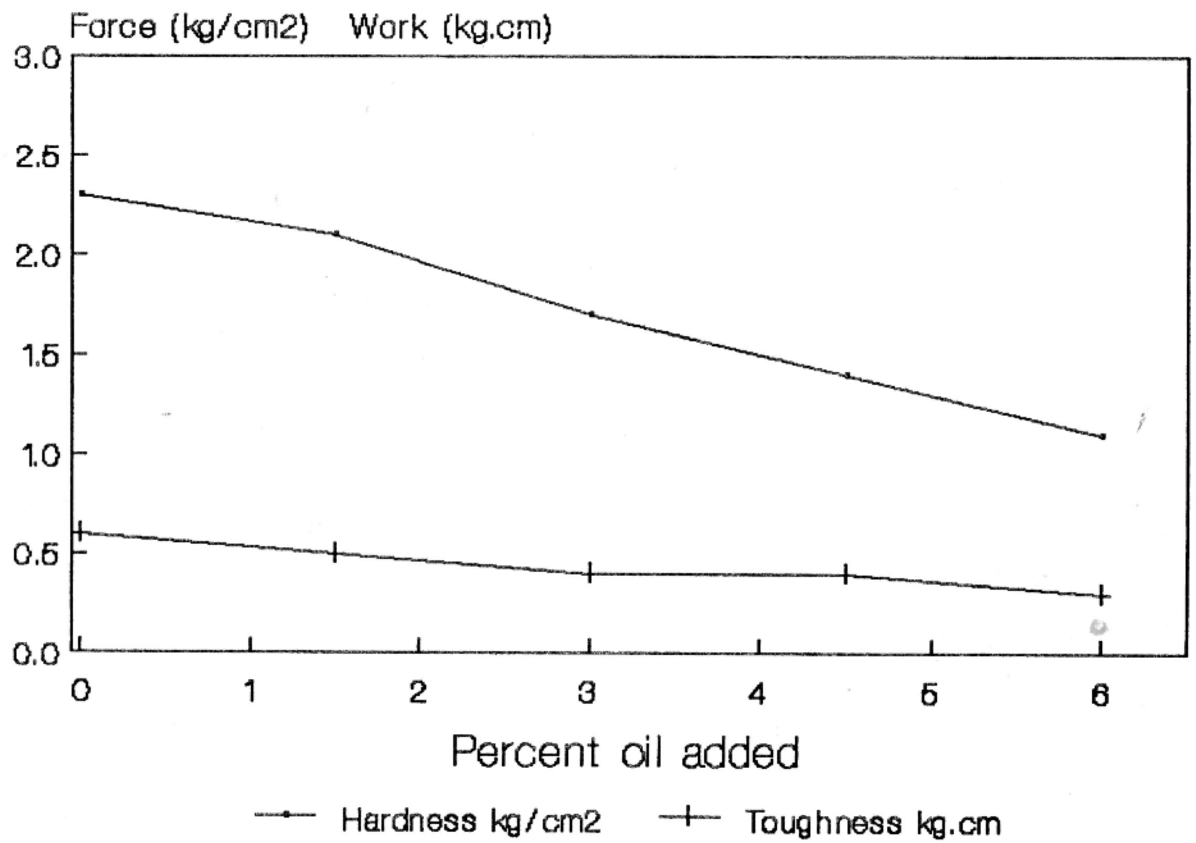

Fig. 5. Effect of oil on textural characteristics of apple bar.

According to this table, there is a considerable reduction in volume when dried apple ring is converted to apple bars. For example, the bulk density of dried apple ring with a moisture content of 6% db increases from 0.38 g cm^{-3} to 1.15 g cm^{-3} (Fig. 6) when converted to apple bars. This means that the volume results in saving packaging material, storage space and perhaps shipping costs. The ranges for compression ratios of different bars containing different levels of moisture content are from 3.0 to 2.28 over the range of 6 to 29% moisture content on a dry wt basis.

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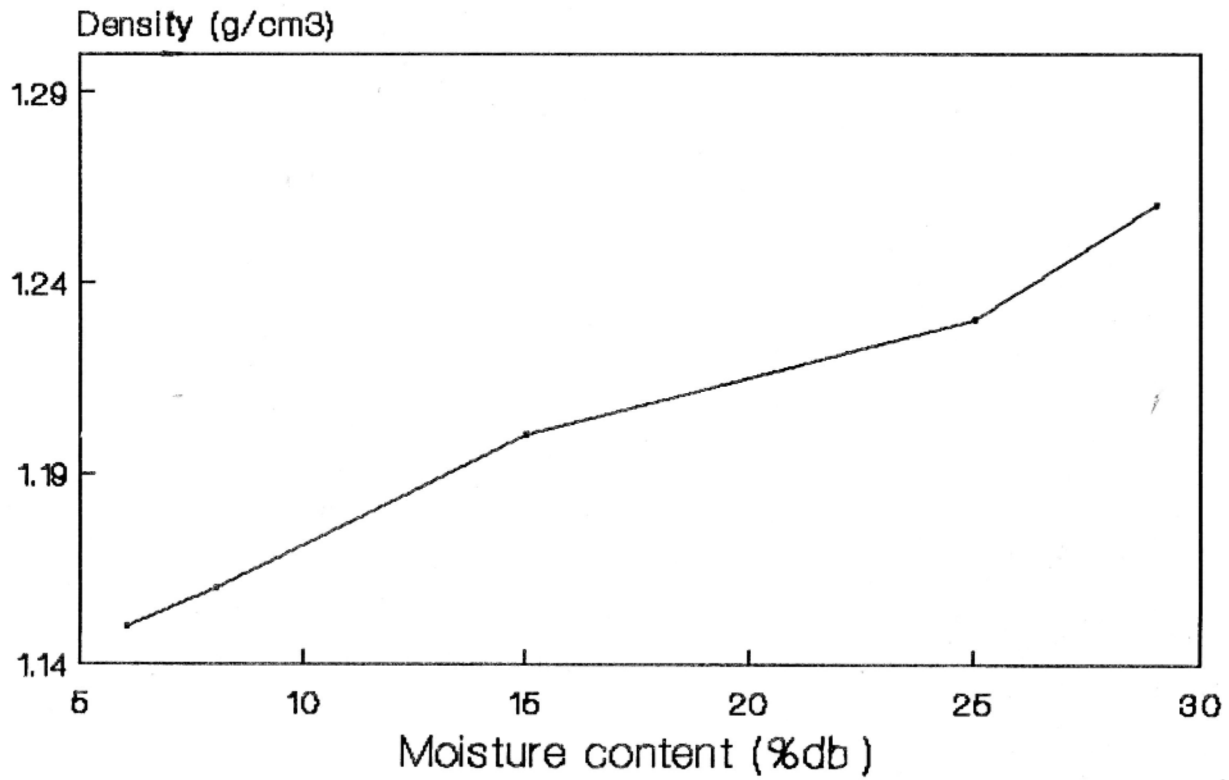

Fig. 6. Bulk density of apple bars as a function of moisture content.

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