Int. Agrophysics, 2008, 22, 299-302

INTERNATIONAL
Agrophysics
www.international-agrophysics.org

Some mechanical properties of barberry

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Received March 25, 2008; accepted August 5, 2008

A b s t r a c t. In this study some mechanical properties of barberry have been evaluated as a function of barberry moisture content varying from 53.11 to 89.23% w.b. The mechanical properties of barberry were determined in terms of average rupture force, deformation and toughness. Samples at various moisture contents were compressed along axis through the width dimension. Physical properties of barberry such as dimensions and geometric mean diameter and volume were determined. In the moisture range from 53.11 to 89.23% w.b., length, width, thickness, geometric mean diameter and volume increased. Deformation increased from 0.340 to 2.381 (mm) as the moisture content increased from 53.11 to 89.23% w.b. Rupture force and toughness decreased from 47.238 to 19.669 (N) and 1.149 to 0.105 (J cm^{-3}), respectively. The results provide useful data to be used by engineers in the design of suitable barberry crushing, sorting and separating machines.

K e y w o r d s: barberry, fruit, moisture content, physical properties

INTRODUCTION

Barberry (*Berberis vulgaris* L., Var. asperma Don, family Berberidaceae) grows in Asia and Europe; the plant is well known in Iran and has been used extensively as a medicinal plant in traditional medicine. The fruit of the plant has been used as a food additive.

In Iran more than 5,000 tonnes of barberries are produced each year (FAO, 2005). Khorasan, located in north-eastern Iran, is the production centre with about 6 000 ha of fields growing barberry. Each year, more than 4 500 t are harvested in the Khorasan region alone. Barberry cultivation in Khorasan is concentrated in the south of the province, especially around Birjand and Ghayen, where environmental conditions *ie* hot weather, low relative humidity, water shortage and soil condition are unfavourable for the growing of other horticultural crops. Mean yearly precipitation is 190.3 and 173.5 mm in Ghayen and Birjand, respectively. Minimum and maximum temperature are -38, +41°C in Ghayen and -15, +44°C in Birjand. About 85% of the production is in Ghayen and about 15% in Birjand. According to evidence, the cultivation of seedless barberry in the south of the province goes back two hundred years. Many papers described detailed information about cultivation, taxonomy, propagation, utilization, and processing of seedless barberry cultivated in the southern parts of Khorasan, Iran.

The plant is a shrub, 1-3 m tall, spiny, with yellow wood and obovate leaves, bearing pendulous yellow flowers succeeded by oblong red berries (Zargari, 1983; Amin, 1991). Medicinal properties for all parts of the plant have been reported, including tonic, anti-microbial, anti-emetic, antipyretic, anti-pruritic and cholagogue actions, and it has been used in some cases like cholecystitis, cholelithiasis, jaundice, dysentery, leishmaniasis, malaria and gall stones (Aynehchi, 1986; Nafissi, 1990; Zargari, 1983). In spite of extensive applications and numerous properties, the mechanism of action in most of its effects is not exactly clear. Some of these properties may occur due to antihistaminic or anticholinergic effects.

Many studies have been reported on the physical, mechanical and nutritional properties of fruits, such as coffee (Chandrasekar and Viswanathan 1999), sunflower (Gupta and Das 2000), cornelian cherry (Demir and Kalyoncu, 2003; Guleryuz *et al*., 1998), rose fruit (Demir and Ozcan, 2001), fresh okra fruit (Owolarafe and Shotonde, 2004), cherry laurel (Calisir and Aydin, 2004; Islam, 2002), Juniperus drupacae fruit (Akinci *et al*., 2004), wild plum (Calisir *et al*., 2005), orange (Topuz *et al*., 2004 and Sharifi *et al*., 2007), gumbo fruit (Akar and Aydin 2005), kiwi fruit (Lorestani and Tabatabaeefar, 2006) and berries (Khazaei and Mann, 2004). But no detailed study concerning the mechanical properties of fresh fruits of barberry was found in the literature.

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The objectives of the work reported in this paper were to determine the average rupture force, deformation, and toughness of barberry under compression over a range of moisture contents.

MATERIALS AND METHODS

The barberry fruits used for this study were collected from the region located in Varangehrood village in Karaj, Iran, in 2007 and they were cleaned to remove all foreign matter. Finally, 2 kg of barberry was obtained. All products were kept at room temperature for two days. Moisture content was immediately measured on arrival. All experiments were carried out at room temperature of 25± 3°C during the laboratory tests. All of the tests were made at the physical and mechanical properties Laboratory of Tehran University, Karaj, Iran.

The barberries were divided into three batches in order to obtain three moisture levels for the experiments. One of the batches was left at the initial moisture content of 89.23 % w.b., while the remaining two batches were conditioned to moisture contents of 70.11 and 53.11% w.b., respectively.

To determine the average size of the barberries, their three linear dimensions, namely, length (L), width (W) and thickness (T), were measured using a digital micrometer having accuracy of 0.01 mm (Fig. 1).

Barberry mass (m) was measured with an electronic balance with accuracy of 0.001 g. The geometric mean diameter (D_g) and volume (V) were calculated using the following equations (Jain and Bal, 1997; Mohsenin, 1970).

$$V = \pi(LWT)/6, \tag{1}$$

$$D_g = (LWT)^{0.333}. \tag{2}$$

Three mechanical properties determined in the study include rupture force, deformation, and toughness in the direction through thickness.

Quasi-static compression tests were performed with a Santam Universal Testing Machine (Model SMT-5) equipped with a 25 kg compression load cell and integrator (Khazaei, 2002). The measurement accuracy was ±0.001N in force and 0.001 mm in deformation. For each treatment 30 barberries were randomly selected and the average values of all 30 tests were reported with speed of 1mm s^{-1}.

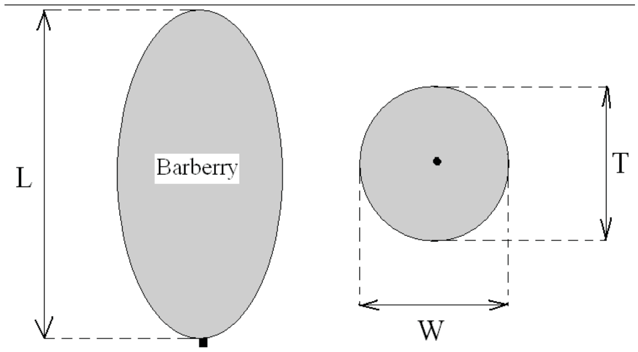

Fig. 1. Three major perpendicular dimensions of barberry.

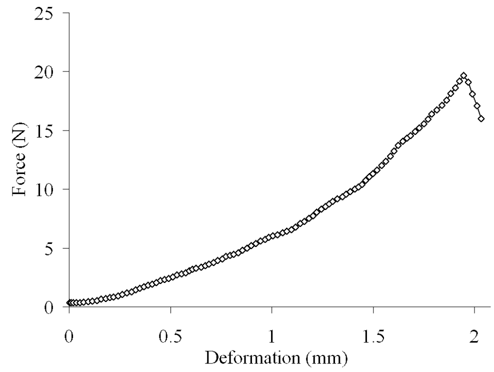

Fig. 2. Typical force-deformation curve for barberry fruit.

The individual barberry was loaded between two parallel plates of the machine and compressed at preset force condition until rupture occurred as is denoted by bio-yield point in the force-deformation curve (Fig. 2). The bio-yield point was detected by a break in the force deformation curve. Once the bio-yield was detected, the loading was stopped. The mechanical properties of barberry were expressed in terms of rupture, deformation and toughness required for initial rupture.

The deformation (strain) was taken as change in original dimension of the barberry. The energy (E) was determined by calculating the area under the force-deformation curve up to barberry rupture. Toughness (P) was expressed as the energy absorbed by the barberry up to rupture point per unit volume of the barberry. This was calculated using the following formula (Olaniyan and Oje, 2002).

$$P = E/V. \tag{3}$$

Variance analysis was carried out on the three moisture content levels of barberries by using the Duncan multiple range tests (SPSS 13.0). Mean values were reported with the standard deviation.

RESULTS AND DISCUSSIONS

Table 1 shows the average barberry geometric properties used in the tests. As it is seen from Table 1, the length, width, thickness, geometric mean diameter and volume of barberry increased with increase in moisture content. This situation stems from water absorption of barberry. Similar results have been reported by Sessiz *et al*. (2007), Razavi *et al.* (2007) for caper fruit and pistachio, respectively.

Table 2 gives the average values of rupture force, deformation and toughness obtained from the experiment at different moisture contents. The standard deviations for the respective mean values are also shown.

T a b l e 1. Chosen properties of barberry at different moisture

Properties	Moisture (%, w.b.)		
	53.11	70.11	89.23
Length[a] (mm)	9.68(0.012)[b]	11.25(0.031)	12.01(0.104)
Width[a] (mm)	2.23(0.002)	4.24(0.001)	5.81(0.031)
Thickness[a] (mm)	2.22(0.001)	4.22(0.002)	5.80(0.006)
Geometric mean diameter[a] (mm)	3.62(0.014)	5.85(0.013)	7.38(0.141)
Volume[a] (mm^3)	25.07(0.134)	105.34(1.302)	211.79(3.001)

[a]Average of 30 tests, [b]standard deviation values in parentheses.

T a b l e 2. Effect of moisture content and compression axis on rupture force, deformation and toughness

Moisture content (%, w.b.)	Rupture force[a] (N)	Deformation[a] (mm)	Toughness[a] (J cm^{-3})
53.11	47.238(1.032)[b]	1.34 (0.038)	1.149(0.044)
70.11	22.612(0.812)	1.83 (0.008)	0.162(0.003)
89.23	19.669(0.213)	2.01 (0.023)	0.105(0.002)

Explanations as in Table 1.

The required force to initiate barberry rupture at different moisture contents is presented in Fig. 3a. The force required to initiate barberry rupture decreased as the moisture content increased from 53.11 to 89.23% w.b. Compressed barberry required 47.238, 22.612 and 19.669 N at the moisture contents of 53.11, 70.11 and 89.23% w.b., respectively. This decrease in rupture force is due to increase in flexibility of fruit internal texture under the effect of increasing moisture content. Also, with decrease of moisture below 53.11% no clear rupture point is seen in barberry fruit.

Similar trends were also observed by Chandrasekar and Viswanathan (1999) for coffee, Gupta and Das (2000) for sunflower, Calisir and Aydin (2004) for cherry laurel, Akar and Aydin (2005) for gumbo fruit. Mathematically, the relationship between moisture content and rupture force of barberry compressed through width can be expressed as follows:

$$F = -0.7074 M_c + 79.20 \qquad R^2 = 0.839. \tag{4}$$

where: F – rupture force, M_c – moisture content.

Figure 3b shows the effects of moisture content on the deformation at rupture. The deformation slowly increased as the moisture content increased from 53.11 to 89.23% w.b. The relationship between moisture content and deformation of barberry was as follows:

$$D = -0.0171 M_c - 0.5302 \qquad R^2 = 0.9404, \tag{5}$$

where: D – deformation.

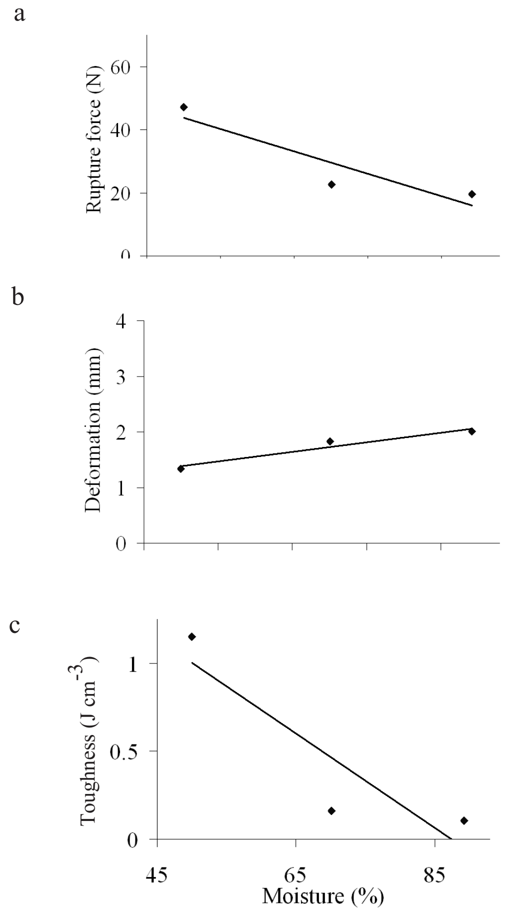

Fig. 3. Effects of moisture content on: a – rupture force, b – deformation, c – toughness for barberry.

The flexibility of the fruit under higher moisture levels is one of the reasons for higher deformation in higher moisture. Another reason is due to skin viscoelastic property which causes higher deformation of the fruit under compression.

From Fig. 3c it can be observed that toughness decreased from 1.149 to 0.105 (J cm^{-3}) with increase in moisture content from 53.11 to 89.23% w.b. This shows the amount of required energy for rupture compared in volume – when the moisture increases, is lower and this causes lower toughness.

This is in agreement with the findings of Oloso and Clarke (1993) for cashew nut and Olaniyan and Oje (2002) for shea nut. The relationship between moisture content and toughness of barberry compressed through width can be expressed as follows:

$$P = -0.0268 M_c + 2.3437 \quad R^2=0.8024, \tag{6}$$

where: P – toughness.

CONCLUSIONS

1. Rupture force and toughness decreased with decrease of moisture content. The rupture force and toughness were 47.238 N and 1.149 J cm^{-3} at moisture content of 53.11% w.b. (lowest moisture content), 22.612 N and 0.162 J cm^{-3} at moisture content of 70.11% w.b. and 19.669 N and 0.105 J cm^{-3} at moisture content of 89.23% w.b. (higher moisture content), respectively.

2. Deformation increased from 1.34 to 2.01 mm with increase of moisture content from 53.11% to 89.23% w.b., and positive linear relationship existed between deformation and moisture content of barberry.

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