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Some physical and mechanical properties of caper

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The physical properties were determined for the length, width, thickness, geometric mean diameter, arithmetic mean diameter, mass, volume, bulk density, sphericity, projected area, and mechanical characteristics; namely Young Modulus, maximum force and required energy for initial fracture at yield point for Caper (*Capparis spinosa*). These properties are necessary in the design of the equipment for harvesting, processing and transportation, separating and packing. The results showed that the mean values of length, width, thickness, arithmetic mean diameter, geometric mean diameter, mass, volume, projected areas perpendicular to the main diameters and sphericity of Caper are 32.34 mm, 24.53 mm, 19.16 mm, 23.59 mm, 22.75 mm, 6.71 g, 6.82 cm^3, 354.69 mm^2, 560.61 mm^2, 576.02 mm^2 and 71.23%, respectively. The average values of Young Modulus, maximum force for initial fracture and required energy at yield point for Caper were 0.112 GPa, 92.247 N, and 304.59 Nmm, respectively.

Key words: Caper, mechanical properties, physical properties.

Nomenclature

M= Castor seed mass, g; V= Castor seed Volume, cm^3; D_g= geometric mean diameter, mm; D_a= arithmetic mean diameter, mm; S_{Mc}= calculated surface area with McCabe Formula, mm^2; S_{JB}= calculated surface area with Jean & Ball Formula, mm^2; L= length of Castor seed, mm; W= width of Castor seed, mm; T= thickness of Castor seed, mm; PA_1= first projected area perpendicular to L direction, mm^2; PA_2= second projected area perpendicular to W direction, mm^2; PA_3= third projected area perpendicular to T direction, mm^2; CPA= criteria projected area, mm^2; ρ_t= true bulk density, $g.cm^{-3}$; Φ= Sphericity(%); R_a= Aspect Ratio(%); SD= standard deviation; CV= coefficient of variation(%); Max= maximum; Min= minimum; mean= Average value; F_{max}= maximum force that is required for fraction, N; W= required energy for initial fraction, N.mm and E= Elasticity modulus, GPa.

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Introduction

Capparis spinosa, the caper bush, is a perennial winter-deciduous species that bears rounded fleshy leaves and large white to pinkish-white flowers. A caper is also the pickled bud of this plant. Caper bush is present in almost all the circum-Mediterranean countries and is included in the floristic composition of most of them but whether it is indigenous to this region is uncertain. The collision pushed up a vast system of mountains, extending from the Pyrenees in Spain to the Zagros Mountains in Iran. Although the flora of the Mediterranean region has considerable endemism, the caper bush could have originated in the tropics, and later been naturalized to the Mediterranean basin. The plant is best known for the edible bud and fruit (caper berry), which are usually consumed pickled. Other species of Capparis are also picked along with C. spinosa for their buds or fruits (Available at http://en.wikipedia.org/wiki/Caper).

The physical properties of Caper are important in the design of equipments for harvesting, cleaning, sorting, grading, packaging and processing. Physical properties of food materials also affect on handling/conveying characteristics and estimating the cooling and heating loads (Mohsenin, 1986). Mechanical properties are needed for texture analysis and better understanding product quality. For example, firmness of horticulture products as measured by instrumental methods is frequently used to determine their maturity and ripeness, which is important in handling, storing and processing procedures. Furthermore, Firmness is a component of texture influencing sensory perception of fruit by consumers. Texture perception and texture acceptability are critical factors in quality evaluation of fruit and vegetable products offered on market. Although, most consumers mentioned taste as most important component of fruit quality, tests indicate that consumers are more sensitive to differences in texture than taste (Shewfelt, 1999).

Since currently used systems have been generally designed without taking these criteria into consideration, the resulting design lead to inadequate applications. This results in a reduction in work efficiency and an increase in product loss. Therefore, determination and consideration of these criteria have an important role in designing the equipments. With respect to economical and processing importance of Caper, overcoming the world market and decreasing product losses, investigation and development in the field of selection or designing of the most suitable machine for it is necessary. But, there isn't study concerning physical and mechanical properties of Caper has been performed up to now. The aim of this research was to investigate the physical-mechanical properties of Caper in order to achieve a complete profile of these attributes. The physical and mechanical characteristics studied were length, width, thickness, mass, volumes, geometric & arithmetic mean diameters, aspect ratio, projected area, sphericity, Young Modulus, maximum force and required energy for initial fracture at yield point.

Materials and methods

Materials

Mature fresh Castors were used for all experiments. Samples were obtained from the Kermanshah province, Iran in July 2011, and kept in a refrigerator until laboratory measurements were performed. 70 samples were randomly selected for all experiments. All the measurements were carried out at the room temperature.

Physical properties determination

Linear dimensions, i.e. length (L), width (W) and thickness (T) were measured using a caliper with an accuracy of 0.01 mm. The arithmetic mean diameter (D_a) and the geometric mean diameter (D_g) were then calculated by the following relationships, respectively (Mohsenin, 1986):

$$D_a = (L + W + T)/3 \quad (1)$$

$$D_g = (LWT)^{1/3} \quad (2)$$

The aspect ratio (*Ra*) was obtained using following relationship as recommended by Maduako and Faborocde (Razavi & Bahramparvar, 2007):

$$R_a\% = \left({}^{W}\!/_{L} \right) * 100 \quad (3)$$

The criteria used to describe the shape of the Caper was sphericity. Thus, the sphericity (Φ) of samples was found according to the relationship given by Mohsenin (1986) as:

$$\Phi = {}^{(LWT^{1/3})}\!/_{L} \quad (4)$$

Surface area is defined as the total area over the outside of the Caper. Surface area (*S*) was theoretically calculated as apparent Surface area using two following equations that given by Jean and Ball (1997), McCabe *et al*. (1987), and Razavi *et al*. (2007).

$$S = {\pi B L^2}/{(2L - B)} \quad (5)$$

Where, $B = (WT)^{0.5}$

$$S = \pi (D_g)^2 \quad (6)$$

True volume and true density were determined by the liquid displacement method (Mohsenin, 1986). Water was used for this purpose. The true volume (V) calculated by the following equation:

$$V = {(M_a - M_w)}/{\rho_w} \quad (7)$$

Where, M_w is mass of sample in water; M_a is mass of sample in air and ρ_w is density of water. Then, the true density of Caper obtained by the following relationship:

$$\rho_t = {M_a}/{V} \quad (8)$$

Mechanical properties determination

The mechanical properties of Caper were expressed in terms of Elasticity (Young) Modulus, maximum force and required energy for initial fracture at yield point. For determination of mechanical properties, Zowick/roell Universal Testing Machine was used which is the popular destructive test device (Figure 2). This method is based on force–deformation characteristics of the caper and evaluation of the rheological properties of Caper is the measure of the maximal force or stress needed to perforate the seed.

In order to do the rheological tests, samples placed on natural rest position and analyses were accomplished in the orientation of thickness. The texture analyzer was fitted with a cylindrical probe (20.17 mm diameter) which was forced into the fruit, at constant speed (10 $mm.min^{-1}$ for Caper) until a deformation equal to 10% of initial samples' length is created. The mechanical parameters of this test such as Young Modulus, maximum force and required energy for initial fracture at yield point for Caper (*Capparis spinosa*) were determined. These were automatically generated as puncture progress, a force–distance and force–time curves was plotted automatically in relation to the response of each sample.

Data analyses

All properties were measured at least in five replications, unless stated otherwise. Maximum, minimum, range, mean, standard deviation, regression equations and coefficient of determination were obtained by a spread sheet software program namely Microsoft Excel (2007).

Results and discussions

Physical characteristics

A summary of the results obtained for physical properties of Caper is shown in Table 1. As it can be seen, the average length, width and thickness were found to be 13.52, 13.39 and 13.38 mm, respectively. The importance of these dimensions in determining aperture size of machines, particularly in separation of materials has been discussed by Mohsenin (1986). The major axis has been found to be indicating the natural rest position of the material and hence in the application of compressive force to induce mechanical fracture. Also, this dimension will be useful in applying shearing force during slicing (Owolarafe and Shotonde, 2004).

The sphericity and aspect ratio of Caper were found to be 99.41% and 99.31%, respectively. The high sphericity of Caper is inductive of the tendency of the shape towards a sphere. Taken along with the high aspect ratio of 99.31% (which relates the fruit width to length), it may be deduced that Caper will rather roll than slide on their flat surfaces. However, the aspect ratio value is being close to the sphericity value may also mean that the Caper will undergo a combination of rolling and sliding action on their flat surfaces.

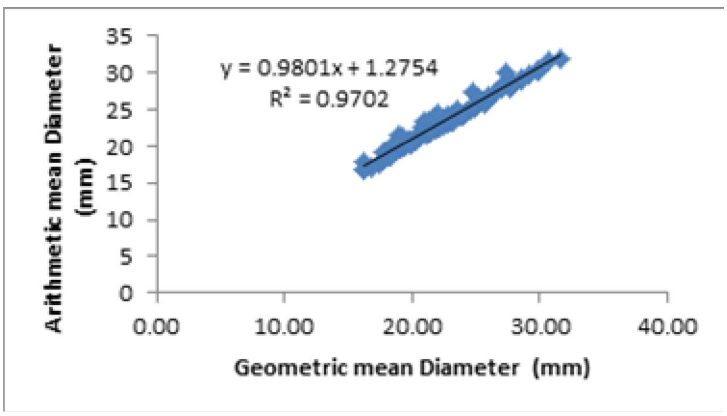

Fig. 1. Relationship between arithmetic and geometric mean diameters of Caper

Fig. 2. Zowick/roell Universal Testing Machine

The relationship between geometric and arithmetic mean diameters of Caper is shown in Figure 2. As this figure indicates, the average diameters calculated by the arithmetic mean and the geometric mean formulas (equations 1 and 2) were almost same. Therefore, either the arithmetic mean or the geometric mean method can be used to calculate the equivalent diameter of Caper. The regression relationship between geometric mean diameter and arithmetic mean diameter was obtained as follows:

D_a=1.019 D_g + 0.386 (R^2= 0.972)

The values of surface area of Caper calculated by two used methods are shown in Table 1. The average values of true volume and true density of Caper were 6.82 cm^3 and 1 $g.cm^{-3}$, respectively (Table 1). These properties may be useful in the separation and transportation of the fruit by hydrodynamic means.

Table 1. Some physical properties of Caper

Physical Properties	Caper			Significativity level
	Max	Min	Average	
L (mm)	49.42	18.53	32.34	P <0.01
W (mm)	34.61	14.37	24.53	P <0.01
T (mm)	28.89	11.15	19.16	P <0.01
M (g)	16.64	2.77	6.71	P <0.01
V (cm^3)	18.86	2.71	6.82	P <0.01
ρ_t ($g.cm^{-3}$)	1.5	0.43	1.00	P <0.01
D_g (mm)	31.68	16.30	22.75	P <0.01
D_a (mm)	31.96	16.74	23.59	P <0.01
S_{MC} (mm^2)	3153.84	834.51	1664.72	P <0.01
S_{JB} (mm^2)	2963.43	706.30	1436.81	P <0.01
Φ (%)	129.07	50.34	71.23	P <0.01
R_a (%)	146.63	35.72	60.73	P <0.01
PA_1 (mm^2)	502.6	232.3	354.69	P <0.01
PA_2 (mm^2)	802.6	349.3	560.61	P <0.01
PA_3 (mm^2)	833.8	349.9	576.02	P <0.01
CPA (mm^2)	704.8	312.4	497.11	P <0.01

Mechanical characteristics

The results of the rheological properties of Caper are presented in Table 2. Elasticity modulus (E), maximum force which caper can support (F_{max}) and work which performed to this force have been determined. These data showed that the caper is designated as soft and elastic fruits.

Table 2. Some mechanical properties of Caper

Parameters	Max	Min	Mean	SD	CV (%)
Young modulus(GPa)	0.247	0.019	0.112	0.07	58.34
Fmax (N)	164.00	52.20	92.247	32.3	35.01
W to Fmax (N. mm)	620.93	113.75	304.591	171.94	56.45

Conclusion

Caper is one of the most important fruits which are the best known for the edible bud and fruit (caper berry), which are usually consumed pickled. Fresh fruits need to be harvested, transported, sorted, graded, packed, etc. As a first step in design of specific equipment for above processes, the properties of the fruit need to be known. This study undertook to determine the relevant physical and mechanical properties of the Caper namely mass, size, sphericity, projected area, arithmetic and geometric mean diameters, true densities, the regression relationships between arithmetic and geometric mean diameters were obtained. This information will facilitate the design of the machines involved.

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