Influence of freeze-drying treatment on the texture of mushrooms and onions

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Summary

In the present work the textural properties of mushroom and onion, fresh and after freeze-drying, were studied, to understand how this drying treatment influences the texture of these food products. The fresh products had average moisture contents of 90.25 % and 90.02 % (wet basis) and the freeze-dried ones had moisture contents of 7.01 % and 5.19 % (wet basis), for mushroom and onion, respectively.

The texture profile analysis (TPA) to the samples of the fresh and freeze-dried mushrooms showed that neither of the samples analyzed possessed measurable adhesiveness, and that hardness decreased very much with drying, either in the cap or in the stalk. Chewiness also varied quite significantly with freeze-drying, contrarily to cohesiveness, which practically stayed the same. Springiness also decreased with drying, although not in a very significant way. When comparing the two parts of the mushroom, it was observed that the cap is much harder, has slightly lower cohesiveness and springiness and a little higher chewiness.

From the TPA to the fresh onion and to the freeze-dried one it was possible to conclude that the hardness of the onion decreased very much from the fresh to the dried state. A similar behaviour was observed for the chewiness, which also decreased, but in a much less extent. On the other hand, cohesiveness increased slightly with drying. In relation to springiness, this property was not affected from drying, being the value in the fresh state quite similar to the value in the freeze-dried state.

Keywords: Mushroom, onion, freeze-drying, texture, TPA.

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1. Introduction

Mushrooms are edible fungi of commercial importance and their cultivation and consumption has increased substantially due to their nutritional value, delicacy and flavor (Giri, 2007). *Agaricus bisporus*, known as button mushroom, is an edible basidiomycete fungus occurring naturally in grasslands, fields and meadows across Europe and North America. Although the original wild form had a brownish cap and dark brown gills, presently the more familiar variant, which it is one of the most widely cultivated mushrooms in the world, has a white form with white cap, stalk and flesh and brown gills.

Mushrooms are soft textured and highly perishable, beginning to deteriorate shortly after harvest (Walde, 2006). Because of their short shelf life under normal ambient conditions of temperature and humidity, their preservation is of most importance. Dehydration, canning, freezing, among others, have been found to be suitable for their preservation (Bernas, 2006; Pal, 1997). Dehydration is one of the important preservation methods employed for storage of mushroom and dehydrated mushrooms are valuable ingredients in a variety of sauces and soups. As mushrooms are very sensitive to temperature, choosing the right drying method can be the key for a successful operation (Giri, 2007).

The preservation of aroma is essential for accessing quality of processed food products, and in particular for the case of mushrooms, which are very much used for culinary preparations because of their unique aroma. Freeze-drying, being a low temperature process, causes less deterioration in the aroma compounds of food products. In this process water is eliminated by sublimation from a frozen state, and the temperature of the product remains very low during the operation (Kompany, 1995).

Onion, *Allium cepa, L.*, is considered one of the most important crops around the world. Onion is a strong-flavored vegetable used in very different ways, and its high contents in organo-sulphur compounds is the main responsible for its characteristic flavor (pungency) or aroma, biological components and medical functions (Corzo Martinéz, 2007).

Bulbs from onion species are widely used in food flavoring, and have been very much appreciated over the years, both because of its characteristic taste and smell and also because they contain significant amounts of some beneficial compounds such as allicin and their derivatives or flavonoid glycosides (Crozier, 1997; Xiao, 2002). Moreover, Allium species are rich in flavonols, among which quercetin, known for its antioxidant and free radical scavenging power and its capability to protect against cardiovascular disease (Clifton, 2004).

For all these reasons, onion can be considered a good antioxidant additive for food (Ostrowska, 2004; Boskou, 2006).

Dehydrated onion is widely used as flavor additive in the manufacture of processed foods such as soups, sauces, salad dressings, sausage and meat products, packet food and many other convenience foods. In fact, the dehydrated form is preferred to the fresh product, because it has better storage properties and is easier to use (Rapusas, 1995; Kaymak-Ertekin, 2005). In addition, the preservation of onion in the dried form is commonly practiced to reduce the bulk handling, to facilitate transportation and to allow the use during the off-season. However, when drying shelf-stable vegetables it is absolutely essential to preserve their desired quality attributes.

Texture is the result of complex interactions among food components. This property of fruits and vegetables is affected by traits such as cellular organelles and biochemical constituents, water content, and cell wall composition. Thus, any external factor affecting these traits can modify texture and can, therefore, lead to changes in final product quality.

The changes in texture occurring during the processing of plant materials or certain physiological events have been related to tissue and cell microstructural changes (Redgwell, 1997; Waldron, 1997; Marsilio, 2000).

In a sensory point of view this property is generally defined as the overall feeling that a food gives in the mouth and is therefore comprised of properties that can be evaluated by touch (Sams, 1999). Bourne (1980) further states that texture is composed of several textural properties which involve mechanical (hardness, chewiness, and viscosity), geometrical (particle size and shape) and chemical (moisture and fat content) characteristics.

The texture parameter, together with appearance and flavour, are the organoleptic quality attributes which determine the acceptability of a food by the consumer. Hence, there has been a great interest in the development of methods to predict and control the texture of plant-based foods, particularly in relation to processing treatments. Instrumental texture profile analysis (TPA) is one of the methods to determine the texture by simulating or imitating the repeated biting or chewing of a food.

In the present work Texture Profile Analysis (TPA) was performed to fresh and freeze-dried onions and mushrooms (in two parts: cap and stalk), to evaluate the influence of this processing operation in the textural properties of these food products.

2. Materials and methods

Button mushrooms (*Agaricus bisporus*) and onions (*Allium cepa, L.*) from a local market were selected and washed. The samples were frozen in a conventional kitchen freezer, and then left in the freeze-drier (model Table Top TFD5505, from Uniequip, Germany) for 38 hours at a temperature between - 47 ºC and - 50 ºC, and a pressure of 5 mTorr (0.666 Pa).

Samples of the fresh and freeze-dried mushrooms and onions were used to calculate the average moisture content, which was measured with a Halogen Moisture Analyser (model HG53, from Mettler Toledo, USA), set to a temperature of 125 ºC and a speed 3 (in the range 1 to 5, being 1 fast and 5 slow).

The texture profile analysis to all the samples was performed using a Texture Analyser (model TA.XT.Plus, from Stable Micro Systems, UK). The texture profile analysis was carried out by two compression cycles between parallel plates performed on cylindrical samples (diameter 10 mm, height 5 mm) using a flat 75 mm diameter plunger, with a 5 seconds interval between cycles. The parameters that have been used were the following: 5 kg force load cell and 0.5 mm/sec. test speed. The textural properties: hardness, springiness, cohesiveness, and chewiness were then calculated after equations (1) to (4) (see Fig. 1):

$$\text{Hardness (N)} = F_1 \qquad (1)$$

$$\text{Springiness (\%)} = \Delta T_2/\Delta T_1 * 100 \qquad (2)$$

$$\text{Cohesiveness (dimensionless)} = A_2/A_1 \qquad (3)$$

$$\text{Chewiness (N)} = F_1 * \Delta T_2/\Delta T_1 * A_2/A_1 \qquad (4)$$

where F_1 is the maximum force, i.e., the force in the first peak, A_1 and A_2 are the areas of the first and second peaks, respectively, and T_1 and T_2 are the time intervals for the first and second peaks, respectively. The area of the negative peak, that should be visible between vertical lines 3 and 4 (the vertical lines are auxiliary to compute the textural parameters), represents adhesiveness, and would be visible only when the food has measurable adhesiveness, which is not the present case. Therefore it is not very visible in the TPA shown in Fig. 1. For the onions, 4 analyses were performed in fresh samples and 6 in the freeze-dried samples. For the mushrooms in the fresh state 4 analyses were performed in the cap (pileus) and 9 in the stalk (stripe), whereas for the freeze-dried mushrooms 9 analyss were performed for each part, cap or stalk.

3. Results and Discussion

Table 1 shows the results of the moisture analysis to the onions in fresh and after freeze-drying. The fresh onions had 90.02 (± 1.20) % moisture (wet basis) and the freeze-drying operation reduced the moisture content to 5.19 (± 0.38) % (w.b.). In the case of mushrooms (Table 2), in the fresh state the moisture content was 90.25 (± 1.26) % (w.b.) and in the freeze-dried state the moisture content was reduced to 7.01 (± 1.24) % (w.b.).

Fig. 1 shows the TPA obtained for the fresh and freeze-dried onion, respectively. It is visible that the hardness of the fresh onion is very much higher than that of the freeze-dried, about 15 N in the fresh against about 3 N in the dried sample. This difference can also be observed in Fig. 2(a), where the average value for the hardness was calculated for all the samples analysed: 4 samples for the fresh product and 6 samples for the freeze-dried onion. The average hardness of the fresh onion was found to be 12.87 (± 2.24) N and that for the freeze-dried was 3.50 (± 0.71) N. It means that for the first bite, the fresh onions would require more energy than the freeze-dried onions, signifying that onions soften with the drying process. Similar trend is observed for the second bite, except that lower energy would be spent in biting the onion samples. The values of the standard deviation indicate some uncertainty in the measurements. In fact, materials of biological nature have very complex internal structures, which may alter the results on the texture analysis, just by changing from one place of the product to another, or even changing the orientation of the fibers arrangement (Guiné, 2011).

In Fig. 2 the textural properties of the onions, fresh and freeze-dried, are presented. Fig. 2(b) shows the average values of the cohesiveness, and it is observed that this property increases slightly with drying, from an average of 0.41 (± 0.03) in the fresh form to 0.65 (± 0,07) in the freeze-dried product. This textural attribute is related to the strength of the internal bonds making up the body of the sample. In the graph of Fig. 2(c) the values found for the average springiness are shown for the fresh onion, 78.72 (± 13.78) %, and for the dried onion, 74.64 (± 4.51) %, in this case the values are very similar, indicating that this drying treatment did not affect the recovery in height after the product has been compressed by the teeth during mastication. Fig. 2(d) shows the chewiness of the fresh and dried onions. Chewiness, which is a measure of the energy required for chewing a solid food until it is ready for swallowing, is higher for the fresh onion. In the fresh state, the onions show an average chewiness of 4.03 (± 0.49) N and after the freeze-drying treatment the chewiness diminished to 1.68 (± 0.32) N.

Fig. 3 shows TPAs obtained for the fresh and freeze-dried mushrooms, respectively. It is visible that the hardness of the fresh samples is very much higher than that of the freeze-dried. Moreover, the differences between the cap and the stalk are much more accentuated in the fresh samples than in the freeze-dried ones.

Fig. 4 shows the values obtained for the textural properties (adhesiveness, hardness, cohesiveness, springiness and chewiness) from the TPA obtained for the samples of the fresh and freeze-dried mushrooms. Fig. 2(a) shows that the freeze-dried mushrooms have no measurable adhesiveness and that the fresh ones show a very small value, almost zero, to this property. This result indicates that the work necessary to overcome the attractive forces between the surface of the vegetable and the surface of the other material in contact with the onion is similar and very low.

In Fig. 2(b) is possible to observe that the hardness is very influenced from the freeze-drying treatment, either for the cap or for the stalk. On the other hand, the cohesiveness (Fig. 2(c)) is neither significantly influenced by the drying treatment nor by the position in the mushroom, and the same can be deduced as to springiness (Fig. 2(d)). On the contrary, the chewiness (Fig. 2(e)) presents a similar pattern to that of the hardness, which is expected since this property results from the product of the hardness by the cohesiveness and by the springiness, and these last two do not change much.

4. Conclusions

In the case of onions, from the TPA to the fresh and to the freeze-dried samples it was possible to observe that the freeze-drying treatment substantially influenced the hardness, which decreases from the fresh to the dried state. The chewiness is another textural property that decreased with drying, although not so strongly as hardness. On the contrary, cohesiveness increases slightly with drying. As to the springiness, its value was not affected with drying, and the value in the fresh state is approximately the same as in the freeze-dried state.

With respect to mushrooms, from the present work was possible to conclude that the adhesiveness is practically zero in the fresh mushrooms and indeed zero in the freeze-dried ones. Hardness decreases very much with this treatment, either in the cap or in the stalk. Chewiness is another textural property that varies quite much with freeze-drying, contrarily to Cohesiveness, which practically does not change. Springiness also decreases with drying, although not in a much accentuated way. When the two parts of the mushroom are compared, it is observed that the cap is much harder (almost 2 times harder), has slightly lower cohesiveness and springiness and a little higher chewiness.

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Table 1 – Moisture content of fresh and freeze-dried onions.

Type of onion	Sample	Moisture content (%)
Fresh	F1	90.59
	F2	88.35
	F3	90.00
	F4	91.13
Medium		**90.02**
Standard deviation		**1.20**
Freeze-dried	L1	4.76
	L2	4.90
	L3	5.00
	L4	5.50
	L5	5.22
	L6	5.77
Medium		**5.19**
Standard deviation		**0.38**

Table 2 – Moisture content of fresh and freeze-dried mushrooms.

Type of mushroom	Sample	Moisture content (%)
Fresh	F1	88.61
	F2	89.91
	F3	91.28
	F4	91.19
Medium		**90.25**
Standard deviation		**1.26**
Freeze-dried	L1	5.26
	L2	7.14
	L3	6.15
	L4	8.18
	L5	6.75
	L6	8.55
Medium		**7.01**
Standard deviation		**1.24**

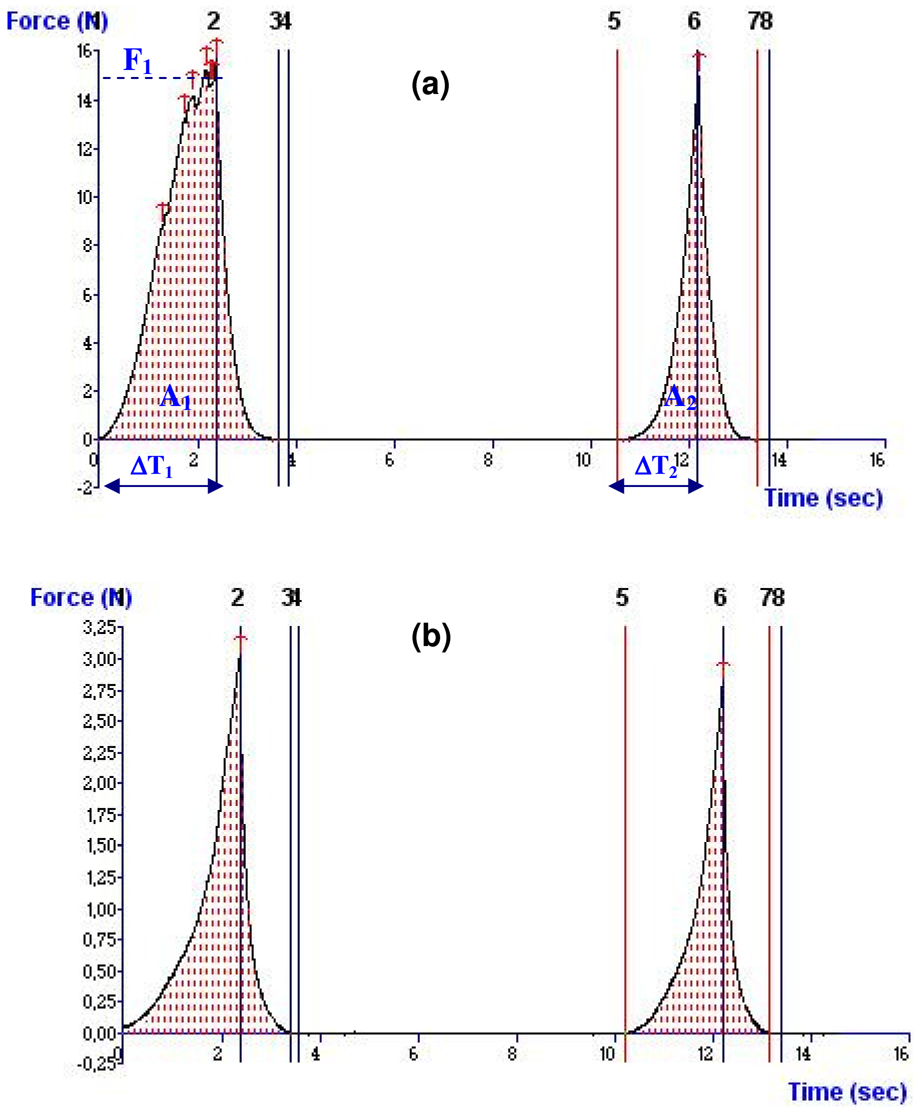

Figure 1 – Texture Profile Analysis (TPA) of fresh (a) and freeze-dried onions (b).

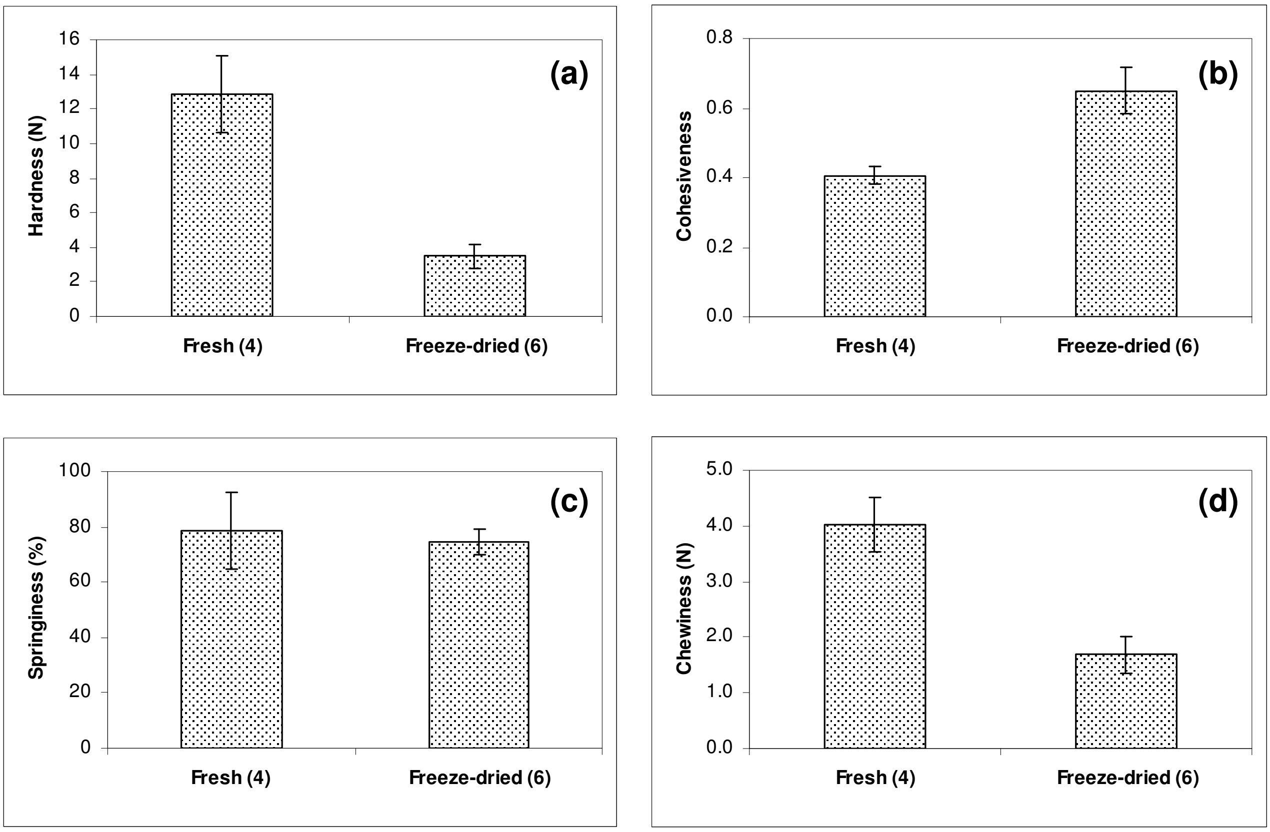

Figure 2 – Textural properties of onions: (a) hardness, (b) cohesiveness, (c) springiness, (d) chewiness (in parenthesis the number of samples).

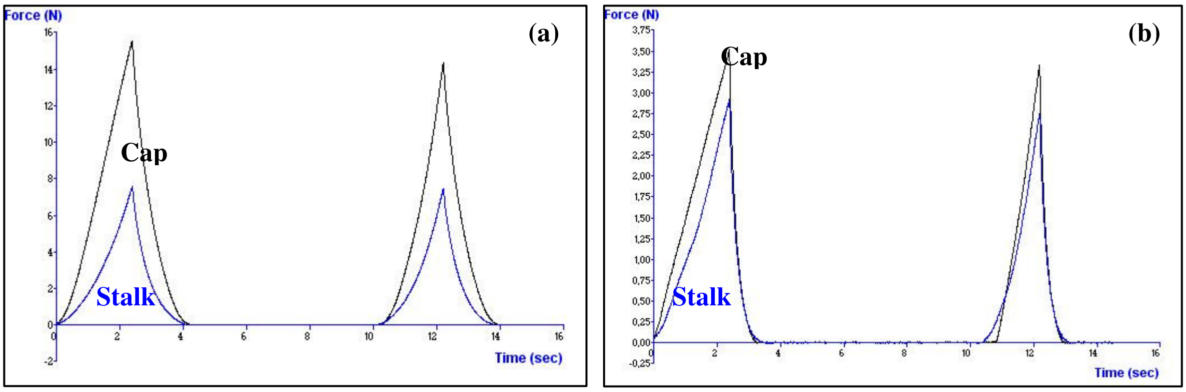

Figure 3 – Texture Profile analysis to the mushrooms: (a) fresh (b) freeze-dried.

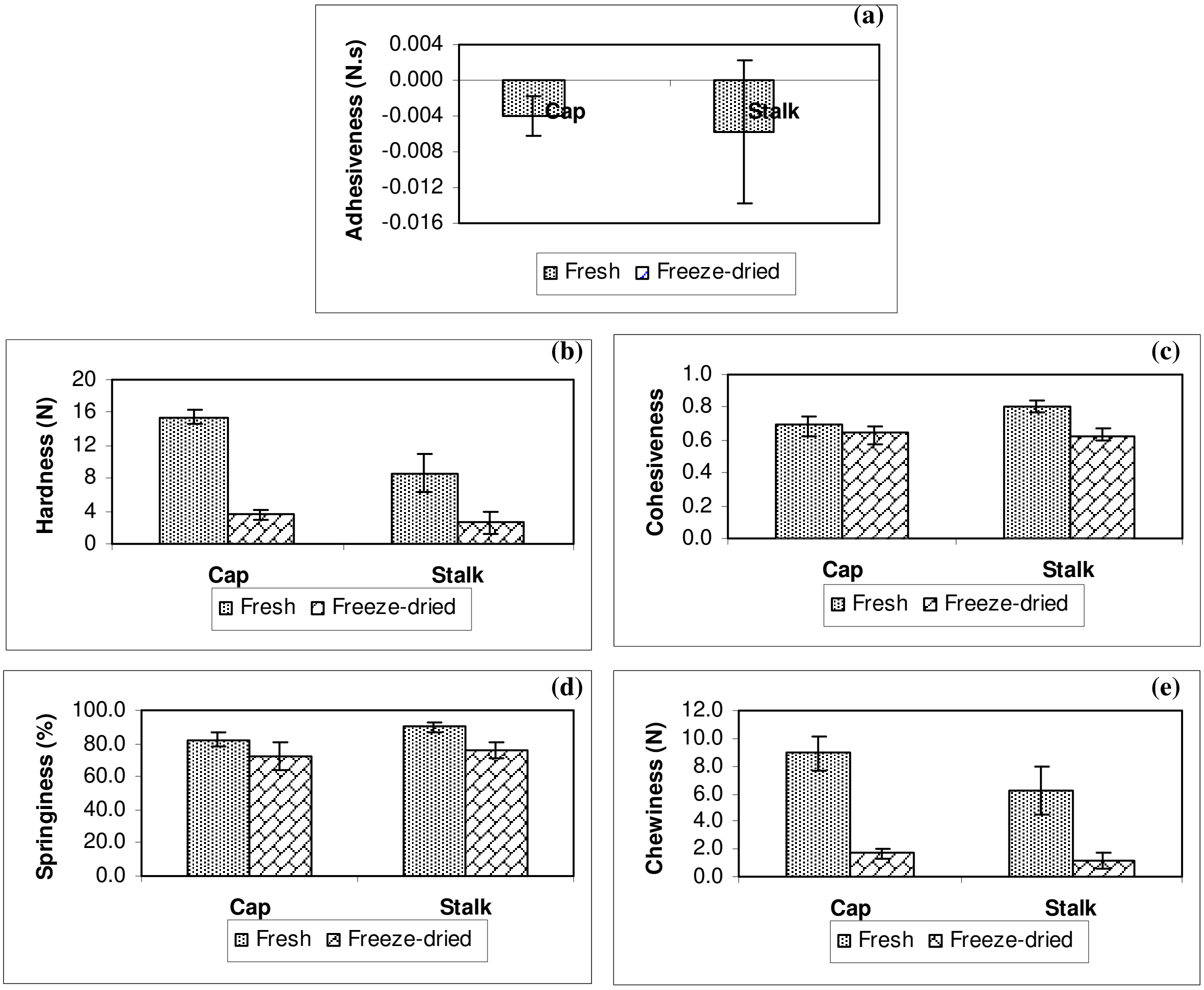

Figure 4 – Textural properties of mushrooms: (a) adhesiveness (b) hardness (c) cohesiveness (d) springiness (e) chewiness.