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Study of some factors affecting water absorption by faba beans during soaking

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Water absorption by faba beans (*Vicia faba*) was determined by recording the weight increase in beans with respect to time. Temperature affected the rate of water absorption since the rates increased with increasing temperatures. The effects of soaking in the different concentrations of sodium bicarbonate have been studied. The rate of water absorption decreased with increasing concentrations of sodium bicarbonate in soaking solutions. The rate of water absorption did not correlate with protein content and it showed little correlation with the size and density of faba beans. A diffusion model was used to describe the absorption of water by beans. Diffusivity was not dependent upon the water content in beans.

INTRODUCTION

Legumes are rich sources of easily available, cheap proteins and complement cereal proteins in terms of several essential amino acids (Liener *et al.*, 1978).

The faba bean (*Vicia faba* L.) is a legume that has long been an important food to people in the Middle East. Different local dishes prepared from faba beans provide a significant amount of plant protein in the diet of many people.

Many workers have reported on the effects of hydration on the cooking time, appearance and palatability of various dry beans. Generally, they stated that hydration is one of the most important factors in producing good-quality products (Jackson & Varriano-Marston, 1981).

In 1920, Shull found that the water-intake curve of xanthium seeds is complex but can be represented by logarithmic equations. He reported that, although temperature affects the rate of water intake, it does not follow the theory of Brown and Worley (1912), which states that the rate of intake is an exponential function of temperature.

The water absorption of soybeans has been studied by Smith and Nash (1961). They reported that, although the rate of water absorption of sound whole beans is influenced by the initial moisture content in the beans, the principal controlling factor is the seed coat. Leopold (1980) studied the imbibition and leakage of soybean cotyledons. He reported that the effect of temperature on the rate of water uptake during the early stage of imbibition can be described by an Arrhenius plot.

Salts are often added to the soaking water to improve certain features in the product. For instance, sodium bicarbonate is used to reduce cooking time of beans (Rockland & Metzler, 1967). Also, ethylenediamine tetraacetic acid and citrate are used to aid in the retention of colour and flavour (Luh *et al.*, 1975; Junek *et al.*, 1980).

In 1961, Powers *et al.* reported that the rate of water imbibition of some varieties of peas and beans was affected by the pH of the soaking solution, but he did not explain how the rate was influenced.

In 1965, Hamad and Powers found that the rate of water imbibition was affected by the pectic content of dry peas and beans.

Many works studied the quantitative analysis of water absorption for wheat, sorghum and corn (Becker, 1960; Chung *et al.*, 1961; Fan *et al.*, 1962), but their models were not suitable to describe the water absorption in legumes.

This study was undertaken to (i) study the effect of processing variables on the rate of water absorption in faba beans, and (ii) develop a means to predict, quantitatively, the water absorption in beans.

MATERIALS AND METHODS

Materials

Sun-dried faba beans (*Vicia faba*) of Giza 1, Giza 2, and Giza 3 varieties, cultivated in Upper Egypt 'El-Menia Governorate' were used in this study.

Processing variables

Effect of temperature. Water absorption data were obtained by placing 15 g of faba beans, after equilibration to the desired temperature, in a strainer, and immersing in a temperature-controlled, deionised water bath. After each period of time, faba beans were removed from the water, superficially dried with facial tissues, and weighed. The difference between the measured weight at a given time and the original weight was the weight gain. Temperatures of 20, 30, 40 and 50°C were used in this study. The weight gains are expressed as a fraction of total amount of water absorbed at time t, W_t/W_∞.

Effect of salt on soaking. To study the effect of salt on soaking, sodium bicarbonate solutions of 0·00, 0·5, 1·0 and 5·0% concentrations were used.

Effect of protein content. The protein content of faba beans was determined by the micro-Kjeldahl method (AACC, 1976).

Effect of the diameter. The average diameter was the arithmetic mean of the longest and shortest dimensions of the beans. Faba beans were assumed to be spherical.

Effect of bean density. The average density of faba beans was calculated by dividing the average weight by the average volume. The average weight of each faba bean variety was determined by weighing approximately 15 g of beans and dividing the weight by the number of beans. Average volume was determined based on the average diameter of beans, assuming that faba beans are spherical.

RESULTS AND DISCUSSION

The results of the absorption measurements at various temperatures (20, 30, 40 and 50°C) are given in Fig. 1. It could be concluded that temperature drastically affected the water absorption. At the lowest temperature (20°C), a rapid initial absorption of water was observed. This may be due to a different absorption mechanism for this period as compared to that for the rest of the curve. At higher temperature, the rapid initially absorbed water was due to the increased diffusion rate at these temperatures. At 20°C, faba beans took 10 h to reach 90% of the total absorption; at 30°C they took 6 h to reach the same level of absorption (90%); at 40°C they took about 4 h, and at 50°C they took 2·5 h.

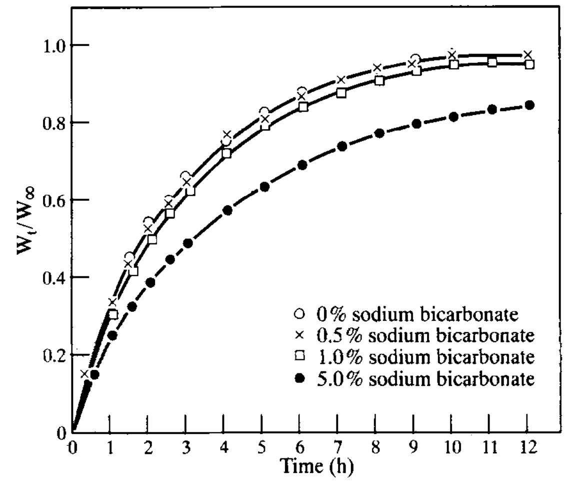

Fig. 2. Effect of Concentration of Soaking Solution (Na HCO_3) of the water absorption of faba beans.

Sodium bicarbonate is usually used with faba beans to reduce the cooking time. The effect of sodium bicarbonate on the rate of water absorption of faba beans is shown in Fig. 2. It was noticeable that the concentration of sodium bicarbonate (0·5%) did not cause significant changes in the rate of water absorption from that of deionised water. At 1% concentration (pH 8·8), a slightly lower absorption rate was observed; and at 5% concentration (pH 9·5), this slower water-absorption rate was even more pronounced. Various factors might have contributed toward the slower water absorption rate which was observed. These factors might include the higher viscosities and lower water activities associated with the increase of sodium bicarbonate concentrations in solutions.

The effect of protein content, size and density of faba beans on the total absorption and absorption rate was investigated. Total absorbed water ranged from 100 to 120% of the original weight of faba beans, depending on variety. The results showed that there was no correlation between the total water absorption and protein content of faba beans (Fig. 3).

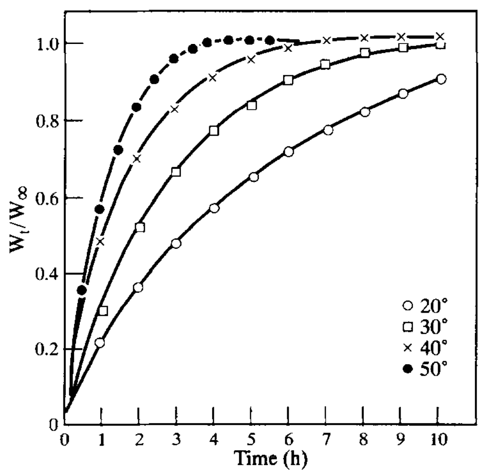

Fig. 1. Effect of temperature on the water absorption of faba beans.

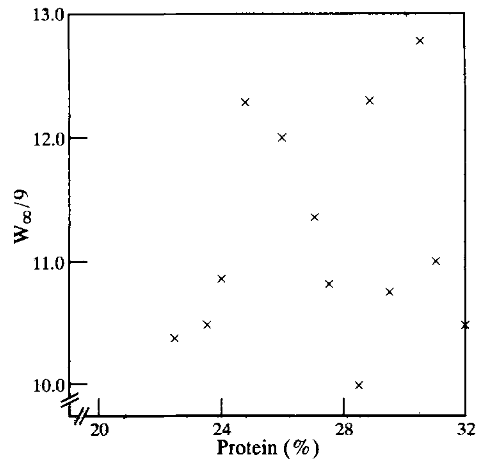

Fig. 3. Relationship between the protein content and the total absorbed water of faba beans.

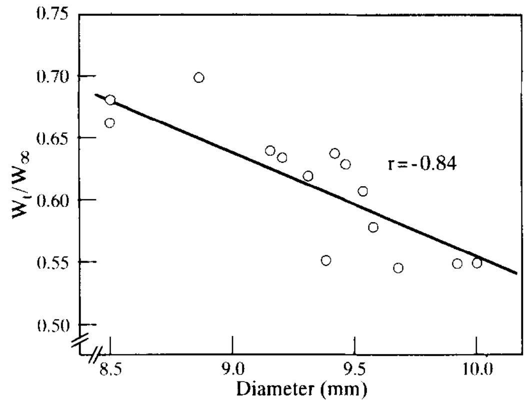

Fig. 4. Relationship between the diameter of faba beans and the fraction of water absorbed after 4 h of soaking

Figure 4 shows a linear correlation between the water absorption rate and the size of the Giza 2 variety of faba beans. The rate of water absorption was expressed in terms of fraction of total water absorbed after 4 h of soaking. A significant correlation was found at $P = 0{\cdot}10$, with the correlation coefficient being $-0{\cdot}84$. This negative correlation between absorption rate and size of beans could be attributed to the smaller size of beans tending to provide a larger surface area per unit mass for mass transfer.

Also, there was a linear correlation between the rate of water absorption and density of beans (Fig. 5). A significant correlation was found at $P = 0{\cdot}05$, with the correlation coefficient being 0·61. This result confirms that the smaller size of beans was associated with higher density. Generally this correlation was not very clear, since the smaller beans provide more surface area per unit mass for mass transfer.

The second objective of this study was to develop a means of predicting water absorption during soaking. This can be approached by the application of Fick's first and second laws together with a mass balance at the interface (surface). So, assuming that the faba bean is spherical, the diffusion equation can be expressed by (Crank, 1975):

$$\frac{dc}{dt} = \frac{1}{r^2}\frac{d}{dr}\left(r^2 D \frac{dc}{dr}\right) \qquad (1)$$

where c is the concentration of moisture, t is time, r is the radical distance and D is the diffusion coefficient.

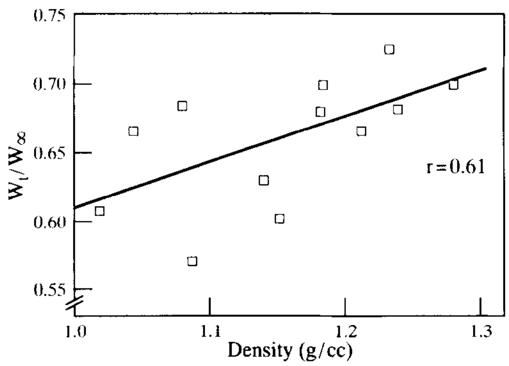

Fig. 5. Relationship between the density of faba beans and the fraction of water absorbed after 4 h of soaking

By making the assumptions (Crank, 1975). that the diffusion coefficient (D) is constant that the effect of volume change is negligible, that surface concentration reached saturation instantaneously upon immersion in water, and that water concentration is evenly distributed before immersion, then eqn (1) is reducible to eqn (2) in terms of fraction of total absorption (W_t/W_∞):

$$\frac{W_t}{W_\infty} = 1 - \frac{6}{\pi^2}\sum_{n=1} \frac{1}{n^2} \exp\left(\frac{Dn^2\pi^2 t}{R^2}\right) \qquad (2)$$

where R is the average radius of the beans. Thus, if D and R are known, the fraction of absorption at any time (t) can be determined.

First, using eqn (2), and then substituting experimentally determined W_t/W_∞, t and R values, the diffusion coefficient (D) can be calculated.

Secondly, also using eqn (2), and the value of D (as estimated), the value of W_t/W_∞ by varying time (t) can be estimated.

Using the results at 30°C, it is found that, to reach 50% of W_t/W_∞, the faba beans must be soaked for 1·9 h. These values were substituted into eqn (2), as well as the R value, and D was determined to be $5{\cdot}98 \times 10^{-7}$ cm^2/s. This value compared well with that reported previously (Hsu *et al.*, 1983).

The calculated value of D was used in eqn (2) to estimate the values of W_t/W_∞ at various times (t). Figure 6 shows a comparison of the experimental absorption curve of faba beans with the predicted curve at 30°C. It can be seen that the predicted curve does not fit very well the experimental absorption curve. Thus eqn (2) was not truly descriptive of the absorption. Evidently, that is because the assumptions made during the derivation of the solution were not appropriate. The constant diffusion coefficient might be one of the assumptions which contributed to the inadequacy of the system. If the diffusion coefficient was constant in the system, the D value calculated by using any point on the absorption curve should give a similar result.

Figure 7 shows the values of the diffusion coefficient calculated by using data from various points on the absorption curve at 30°C. D was strongly dependent upon

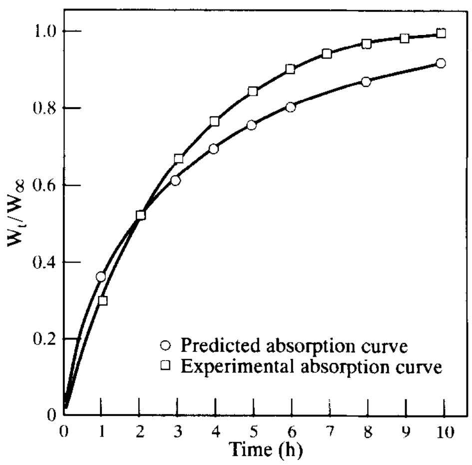

Fig. 6. Comparison of experimental absorption curve of faba beans and the predicted one at 30°C.

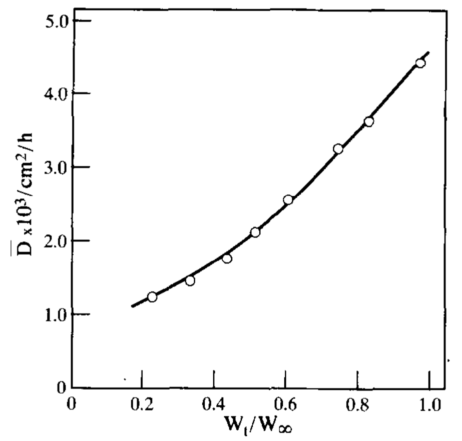

Fig. 7. The diffusion coefficient from various points in the absorption curve.

the moisture content, and the dependence of *D* on moisture content may be exponential in nature.

Finally, this study confirms that the rate of water absorption by faba beans is dependent upon the temperature and the concentration of the soaking solution. The rate of water absorption by faba beans did not correlate with the protein content, but it correlated with the size and density of beans, even though these correlations were relatively low. The diffusion coefficient in faba beans was not constant. Therefore, a diffusion system with a concentration-dependent diffusion coefficient is needed to accurately describe the water absorption of beans.

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