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Properties of walnut influenced by short time microwave treatment for disinfestation of insect infestation

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A B S T R A C T

Insect infestation is the major cause of losses in many stored products such as grains, seeds, cereals and nuts. The use of chemicals to control insect infestation has widely been adopted but now is a cause of concern because of hazardous side effects. Alternative quarantine methods such as ionizing radiation, controlled atmosphere, conventional hot air treatment and dielectric heating have been suggested. Recent studies have indicated that microwave treatment is a potential means of replacing other techniques because of selective heating, absence of pollution in the environment, the achieving of equivalent or better quality retention and energy minimization. However improper application of microwaves can cause irreversible changes in the quality of the final product. The main objective of this research is to evaluate the effect of microwave power level and exposure time on the quality of walnuts. The quality parameters studied were water activity, colour change, temperature rise, peroxide value (PV) and free fatty acid levels (FFA). It was found that microwave power level and exposure time significantly affected colour change and temperature rise. Untreated walnut kernels exhibited significantly higher ($p < 0.05$) peroxide and FFA values than treated walnut kernels. Microwave treatment to target temperatures of 50–55 °C (which is unfavourable for insect survival) made the PV of walnut drop down to between 1.35 and 1.42 meqO_2/Kg (from the initial value of 2.89 ± 0.048) and FFA value to 0.63–0.69% (from 1.08 ± 0.037).

1. Introduction

The walnut is a highly appreciated nut because of its unique organoleptic characteristics (Lopez et al., 1995) and good sources of dietary fibre, various vitamins and minerals USDA, (2011). Walnut is being used as ingredient in a variety of bakery products such as breads, muffins, cakes, biscuits and confectionery as well as flavouring agents in beverages and ice-cream. Walnut kernels have a lipid content of 65% (Vanhanen and Savage, 2006) of which 7% is saturated, 20% is monounsaturated and 73% is polyunsaturated fatty acids (Crews et al., 2005), although values do vary between cultivars (Zwarts et al., 1999). Compared with most other nuts, which contain mostly monounsaturated fatty acids (MUFA), walnuts are highly enriched in omega-6 and omega-3 polyunsaturated fatty acids (PUFA), which are essential dietary fatty acids (Amaral et al., 2003).

India had an annual walnut production of approximately 285 thousand MT in 2011–12, and has exported 5300 MT of walnuts. Major export destinations (2012–13) of walnut from India are United Kingdom, Netherlands, Germany, United States, China, Australia and Taiwan.

(http://www.apeda.gov.in/apedawebsite/SubHead_Products/Walnuts.htm). Almost all countries have imposed a zero tolerance of insects on imported food products. One of the main problems in production, storage, marketing and exporting of dried fruits/nuts is the loss caused by insect infestation. It is estimated that more than 50% of the crop is lost annually due to pests and diseases in nuts (Haribabu et al., 1983). Some estimates put the loss of food grains because of infestation at 40% of world production valued at billions of dollars. Nuts suffer serious damage and loss because of insect infestation during long term storage. Also, Nagaraja, (1998) reported that any bruises in the nuts make the fats liable to become rancid, and thereby integrity of the kernels is lost.

The nut industry relies heavily on fumigation with methyl bromide (MeBr) and hydrogen phosphine for postharvest insect control (Carpenter et al., 2000). Owing to the regulatory actions against the continued use of MeBr, widespread resistance to hydrogen phosphine and public concern over residues in treated products, there has been great interest in developing technically effective and environmentally sound quarantine methods, especially thermal

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ones. An important key to develop successful thermal treatments is to balance needs for a complete kill of insects with a minimal thermal impact on product quality. A common difficulty in using conventional hot air disinfestation methods is the slow heating rate, non uniform temperature distribution, and possible heat damage to heat–sensitive commodities (Hansen, 1992; Tang et al., 2000; Wang et al., 2001). The irradiation process is an efficient method of disinfestation but users are reluctant to accept the process due to safety aspects associated with the irradiation and also it is not available everywhere. Controlled atmospheres require longer treatment times and are not suitable for dealing rapidly with high levels of infestation. Recent studies have indicated that microwave (MW) treatment is a potential means of replacing other techniques as it provides several advantages, namely shortening of treatment time, equivalent or better quality retention, energy minimization, saving in floor space and killing of micro-organisms. Microwave radiation with good penetrability can kill pests existing inside or outside grain kernels. However, in India there is currently little emphasis on use of microwave heating technology for disinfestation applications.

Improper application of microwave energy can cause irreversible changes in the quality of dried products. Microwave heat treatment of whole-kernels needs to be properly controlled because it does not only contribute to change in flavour and aroma but also to the colour of the nuts. Colour is an important quality indicator of the heating process. The effect of heating conditions on changes in colour were reported by several workers in their studies on peanuts (Cammerer and Kroh, 2009), hazelnuts (Özdemir et al., 2001; Özdemir and Devres, 2000), sesame seeds (Kahyaoglu and Kaya, 2006) and macadamias (Wall and Gentry, 2007). Other studies have reported the effect of heating on nutritional composition (Kashani and Valadon, 1983, 1984; Buranasompob et al., 2007; Kita and Figiel, 2007) and storage stability of pistachios nuts (Raei et al., 2009; Nikzadeh and Sedaghat, 2008). The high levels of polyunsaturated fatty acids make walnuts prone to oxidative and hydrolytic rancidity which is linked to the appearance of unpleasant odours and flavours (Watkins, 2005). Peroxides are the product of oxidation of unsaturated fatty acids. Oxidative rancidity is enhanced by the presence of oxygen, increased temperatures and storage times. Hydrolytic rancidity, on the other hand, results from enzymatic hydrolysis of triacylglycerols and the release of free fatty acids (FFA). Free fatty acids contribute off-flavours in walnuts. Therefore, the peroxide value (PV) and free fatty acid content (FFA) of walnuts has also been selected as an indicator of walnut quality.

In this paper, the effect of microwave (MW) power levels and exposure time on moisture content, surface temperature rise, water activity, colour change, and composition (PV and FFA) of walnut kernel were studied and analysed using response surface methodology.

2. Methods

2.1. Materials and experimental set up

A domestic microwave oven (LG, Intellowave 3850w2G031A) with maximum output of 900 W at 2450 MHz was used for the experiments. An outlet was provided on the left upper side of the microwave oven to allow the removal of water vapour. The oven was fitted with a glass turntable (30 cm diameter) and had a facility to adjust the microwave output power by 20% decrements and the time of processing.

The shelled walnut kernels (Variety: Kashmir budded, Grade designation: Light half) procured from a local market were used for experimentation and graded by size to eliminate the variations with respect to exposed surface area. About 200 g of fresh samples were taken for each experiment. A container made of polycarbonate with provision to spread the samples uniformly was placed inside the microwave oven cavity for an even absorption of microwave energy. The experiments followed a factorial design. Table 1 shows the experimental design parameters. The ranges of experimental parameters were selected based on preliminary trials. The independent variables considered were: microwave power level (240, 360 and 480 W) and exposure time (30, 60, 90, 120, 180, 240 s). The response functions (dependent variables) were temperature rise (T_r), colour change (C_{ch}), water activity (a_w), peroxide value (PV), and free fatty acid content (FFA). Each treatment (power and exposure time combination) was replicated 3 times.

2.2. Quality attributes

A standard hot air oven method (AOAC, 2002) was used to determine the initial moisture content of walnut kernels. Nuts were first ground and then 2–3 g flour samples were placed in Petri-dishes and kept in a hot air oven at 80 °C for 24 h. There were three replicates for each measurement. The experiments were conducted at microwave power level 3 and six levels of exposure time respectively. For moisture loss analysis, fresh walnuts were exposed to different power levels and exposure times. The weight loss of sample with time for each run was recorded. The moisture content (% wb) was estimated using standard techniques.

The water activity of samples was determined as a measure of storage stability using a water activity meter (Decagon Devices, Inc., USA, Model No: CX-3TE) which had a dielectric humidity sensor to measure the water activity of a sample. Two replicates were made for each sample and the mean of 3 readings taken for each replicate was used for analysis.

The colour of the samples was measured with a Hunter Lab Colour meter (USA, Model No: Colour flex 45/0) and calculated in terms of colour difference (C_{ch}) (see Eq. (1)) which indicates the degree of overall colour change of a sample in comparison to a fresh sample, examining colour values of L*, a*, and b*. The less the C_{ch} value, the closer it was to the untreated sample.

$$C_{ch} = \left[\left(L - L^*\right)^2 + \left(a - a^*\right)^2 + \left(b - b^*\right)^2\right]^{0.5} \tag{1}$$

Untreated walnuts were taken as the optimal sample having L*, a*, and b* values of 42.64, 6.55 and 14.20 respectively.

Surface temperatures of nuts were measured using a noncontact infrared thermometer (DIT 130, range −32 to 380 °C, Germany). A microwavable rectangular box was made to hold 100 g of sample. The nut samples were immediately kept in the box after the treatment and surface temperature was measured. Ambient room temperature (29 °C) was used as the initial sample temperature for each test.

Peroxide value (PV) and free fatty acid content (FFA) of treated samples was carried according to AOAC standards, 1998 [965.33, 940.28].

Table 1
Experimental details (process parameters and their levels).

Factors	Levels	Variables
Microwave power (W)	240, 360, 480	•Temperature rise
Exposure time (sec)	30, 60, 90, 120, 180, 240	•Colour change
		•Peroxide value
		•Free fatty acid value