RESEARCH ARTICLE FOOD SCIENCE RESEARCH JOURNAL Volume 3 | Issue 1 | April, 2012| 69-73

Dehydration of vegetables by application of radio frequency heating

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Radio frequency (RF) energy as emerging drying technologies. When properly applied can be energy efficient and had great potential in food and allied industries for a wide range of materials. The present investigation was undertaken to study the dehydration of vegetables by application of radio frequency (RF) heating. The dehydration of carrot and cabbage with initial moisture content 89 per cent, and French bean with 90 per cent was carried out for 180 min, 120 min and 180 min, respectively to achieve final moisture content of 5.1 for carrot,1 per cent for cabbage and French bean. The overall quality of RF dried product was observed to be superior over hot air drying.

How to cite this article **:** Babar**,** K.P., Shastri, P.N., Khogare, D.T., Thorat, S.S. and Gaikwad, R.S. (2012). Dehydration of vegetables by application of radio frequency heating. *Food Sci. Res. J.,* **3**(1): 69-73.

Key Words **:** Radio frequency, Vegetables and drying

INTRODUCTION

Drying refers to a process in which water is removed from a moist material by using heat as the energy input. The mechanism of drying is a complex phenomenon involving combined heat and mass transfers within a biological food material. The drying has been reported to account for anywhere from 12 per cent to 20 per cent of the energy consumption in the industrial sector (Raghavan *et al.*, 2005). It is an energy-intensive process because the latent heat is to be supplied to the material to evaporate the moisture. Drying offers a means of preserving foods in a stable and safe condition as it reduces water activity and extends shelf-life much longer than that of fresh foods and agricultural products. A major challenge of drying fresh foods and agricultural products is to reduce the moisture content to a certain low level while maintaining the quality attributes such as colour, texture, chemical components and shrinkage. In conventional heating, such as hot air and infrared drying, thermal energy is transferred from material surface to interior due to temperature gradients. These drying processes have low drying rates causing long drying times in the falling rate period of drying. The long drying times at relatively high temperatures often lead to undesirable thermal degradation of the finished products (Mousa and Farid, 2002 and Zhang *et al.*, 2006). Unlike conventional thermal processing in which energy is transferred from a hot medium to a cooler material through convection, conduction and radiation, dielectric heating involves the dissipation of the electromagnetic. Research on RF heating applications in the food industry started in the 1940s (McCormick ,1988 and Anonymous 1993). The first attempts were to use RF energy to cook processed meat, to heat bread and dehydrate vegetables (Moyer and Stotz , 1947 and Kinn, 1947). Thawing of frozen products was the next step on the application of RF energy in 1960s (Jason and Sanders, 1962). Demeczky showed that juices (peach, quince and orange) in bottles moving on a conveyer belt through a RF applicator had better bacteriological and organoleptic qualities than juices treated by conventional thermal methods (Demeczky, 1947). The primary application in the late 1980 s was the post-baking (final drying) of cookies and crackers (Anonymous, 1987 and Rice, 1993). RF drying methods provide opportunities to shorten drying times and improve the final quality of the dried products. RF energy in

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industrial drying applications is little known to the public and even within general research communities. Jones reviewed the heating principles, generators and applications of dielectric drying of PVC welding, preheating of moulding polymers and drying of a range of non-metal products. He also reported new developments of dielectric (RF) drying systems. Marra *et al.* (2009) reviewed the history, basic principle and recent RF heating applications to food. Zhang *et al*. (2006) provided an general review of recent developing in combined microwave drying with other conventional methods (Zhang *et al.*, 2006).

The growth in popularity of convenient foods in many Asian countries has stimulated increasing demand for high-quality dehydrated vegetables and fruits. India can become one of the largest fruit and vegetable exporters in the world and can equally be a large importer given its demographic diversity. This strong footing in agriculture provides a large and varied raw material base for food processing. The Indian food–processing industry is primarily export oriented. India's geographical situation gives it the unique advantage of connectivity to Europe, the Middle East, Japan, Singapore, Thiland, Malaysia and Korea.

Dehydration plays an important role in the preservation of agricultural products like vegetables. They are defined as a process of moisture removal due to simultaneous heat and mass transfer. The most important reasons for the popularity of dried products are longer shelf-life, product diversity as well as substantial volume reduction. This could be expanded further with improvements in product quality and process applications. Vegetables are so common in human diet that a meal without a vegetable is supposed to be incomplete in any part of the world. The preset investigation was undertaken with an objective to study the dehydration of vegetables by application of radio frequency (RF) heating.

Radio-frequency dryer, the alignment of molecules of the dielectric materials changes rapidly at the radio frequency field. Since heat is defined as a motion of molecules, increasing the molecular motion generates heat. The electromagnetic energy heats the desired material directly without affecting the surrounding structure or the air within it. The entire material of product is heated uniformly without being dependent on the thermal conductivity of the material Dielectric heating is fast, uniform, energy efficient and clean. Drying of fruits, vegetables spices is of great technological interest and has a long tradition as a conservation method. Longer shelf life, substantial weight and volume reduction are the main advantages for its popularity. In the recent years focus has shifted from mere preservation to the preservation of quality, which means improvement in product quality and process application.

METHODOLOGY

The study of utilization of radio frequency energy for drying of vegetables was carried out in the Department of Food Technology, Laxminarayan Institute of Technology; RTM Nagpur University, Nagpur (MS), INDIA. The details of materials used and methods adopted during the present investigation are presented in this paper.

The carrot, cabbage and French bean used in the experiment were obtained from a local market, they were then sorted manually based on their size, washed with hydrogen peroxide (1%) and then with distilled water to make sure the carrot tissues were free of mud particles and other extraneous material and wiped with muslin cloth to remove surface water. The carrots were then peeled manually by using peeler, shredded into dices of 1-2 mm by using knife.

Chemicals and glassware:

The analytical grade chemicals from Himedia, Emerck, and BDH Mumbai and Glassware from Borosil were used.

Dehydration of vegetables and quality evaluation of dehydrated products:

The previously made carrot dices were directly used for dehydration in RF and carried out dehydration. And pretreated cabbage and French bean were used for dehydration in RF. The samples were analysed for moisture, dehydration, dehydration ration and coefficient of rehydration by using procedure described by Ranganna (1986). Quality evaluation of dehydrated products was carried out by Ranganna (1986).

Drying (RF):

RF dryer fabricated by SAMEER with capacity of 15KW, which is capable of evaporating water of the rate of 15 kg/h, was used to dehydrate the Carrot, cabbage and French bean at 0.4 to 1 Amp current. The target of dehydration was kept till the final moisture of the dehydrated vegetables reaches to 5 per cent moisture.

Estimation of B carotene in carrot and total chlorophyll in green vegetables:

The estimation B carotene was done as per standard AOAC method. Extracting samples with 40 ml acetone and 60 ml hexane mixture and measuring absorbance *A* at 436 nm and calculating with formula gives carotene concentration in mg/lb. The chlorophyll in green chili was estimated by measuring optical density of an ether extract of sample at the wavelength 660 nm and 642.5 nm (Ranganna, 1986).

Estimation of acidity in vegetables:

Determine titratable acidity using standard NaOH (0.1) to a faint pink colour with phenolphthalein indicator.(Ranganna-1986).

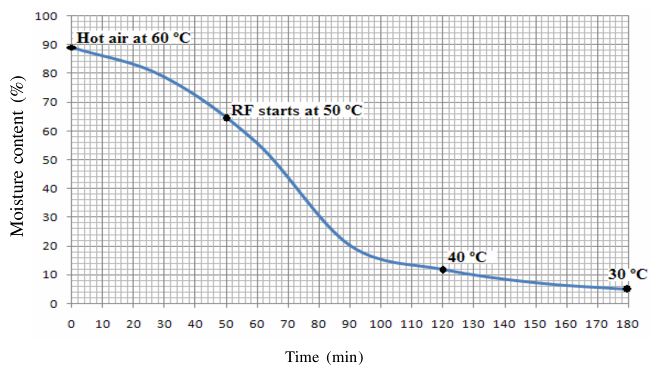
Observations and Assessment

The results obtained from the present investigation as well as well as relevant discussion have been presented under following heads :

Dehydration of carrot, cabbage and spinach:

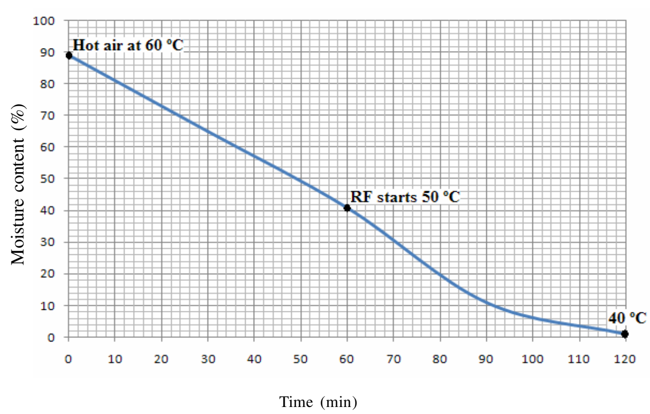
In this experimental work dehydrated carrot, cabbage, French bean by giving pretreatments of steam blanching for 4 min to all vegetables and 1per cent calcium chloride dip for 5 min to carrot to improve texture and 2 per cent sodium bicarbonate dip for 5 min for cabbage and French bean for retention of chlorophyll pigment.

Graphs of time Vs moisture content are indicating drying curve characteristic of vegetables (Fig. 1, 2 and 3)



RFD settings-1 hr Hot air at 60ºC and RF for 2 hr at 50 to 30ºC, RF current-0.8 to 0.5 A

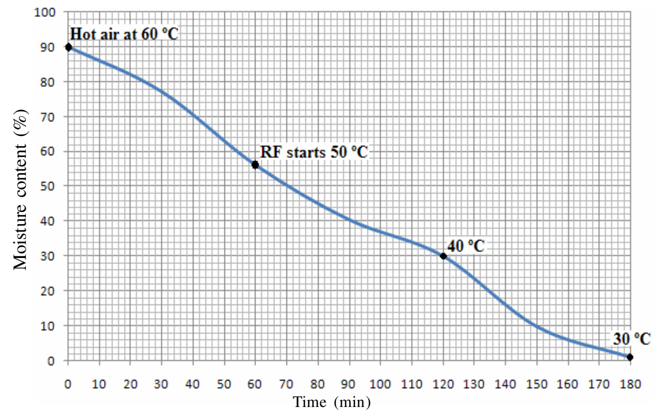
Fig. 1. Dehydration of pretreated carrot by RF dehydration assisted with hot air



RFD settings- 1 hr Hot air at 60ºC and 1 hr RF for at 50 to 40ºC, RF current- 0.7 to 0.6 A

Fig. 2. Dehydration of pretreated cabbage shred by RF drying assisted with hot air

Observation recorded, shows that dehydration of carrot with initial moisture content 89 per cent, cabbage with 89 per cent and French bean with 90 per cent was carried out in180



RFD settings- 1 hr Hot air at 60ºC and 2 hr RF for at 50 to 30ºC, RF current- 0.5 to 0.4 A

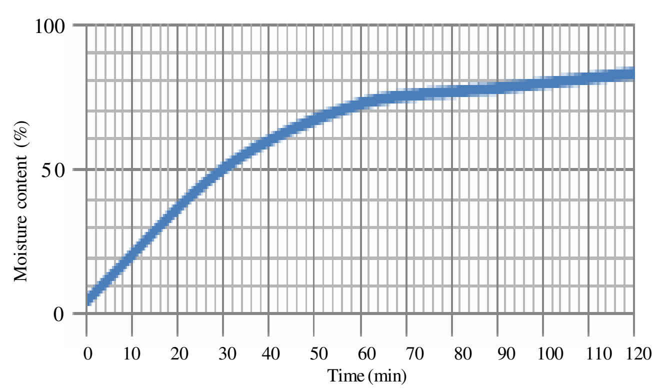
Fig. 3. Dehydration of pretreated French bean by RF drying assisted with hot air

min, 120 min and 180 min, respectively. Final moisture content of carrot was recorded as 5 per cent, for cabbage and French bean as 1 per cent.

Rehydration studies were carried out under the ambient temperature to avoid the solid loss. Rehydration was very fast in initial stages and declined thereafter. Rehydration time was same for all vegetables *i.e.* 120 min. at the end moisture content were achieved 83.7 per cent, 85 per cent and 83 per cent of carrot, cabbage and french bean, respectively (Fig. 4, 5 and 6).

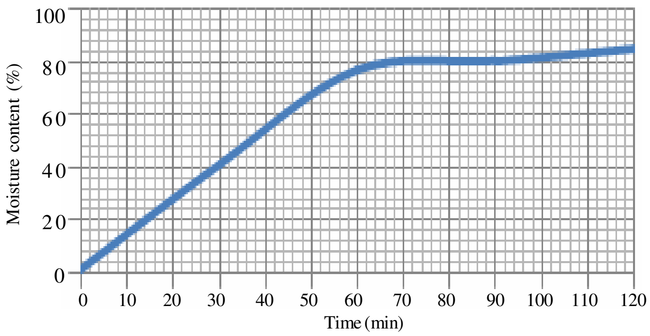
Coefficient of rehydration was calculated by considering the dry weight of vegetables. carrot and French bean has coefficient of rehydration 0.68 and 0.94 was observed in cabbage. In cabbage coefficient of rehydration was more than carrot and French bean. Cabbage more soft tissues than carrot and French bean.

Per cent retention of carotene in dehydrated carrot cubes was 76.08 per cent. in cabbage and French bean observed that per cent retention of chlorophyll was 96.55 per cent and 97.68



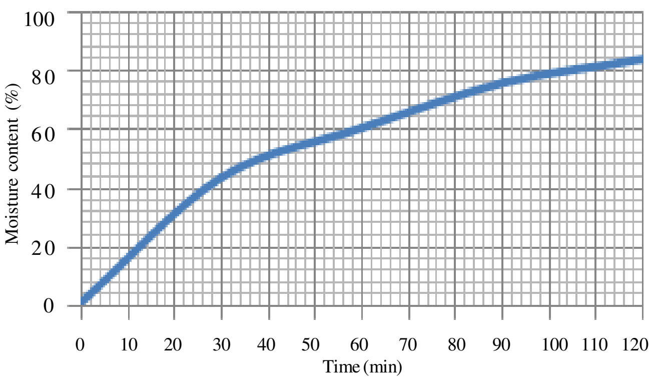
me (min)	0	30	60	90	120
Moisture	50.3	72.6	78.4	83.7	5

Fig. 4. Rehydration data curve of RF dried carrot



me (min)	0	30	60	90	120
Moisture	1	40.8	76.4	80	85

Fig. 5. Rehydration data curve of RF dried cabbage



me (min)	0	30	60	90	120
Moisture	1	43.2	60	75.7	84

Fig. 6. Rehydration data curve of RF dried french bean

per cent, respectively. Retention of quality parameters like carotene and chlorophyll was more because of pretreatments.

The overall quality of RF dried product was observed to be satisfactory. This may be due to fact that in RF drying water movement through the product facilitated by RF waves, rather than by capillary action, was of happens hot air drying. Thus movement of solids was avoided. RF heats the all parts of product mass simultaneously and evaporates the water at relatively low temperature usually not exceeding 60^{0}C. Surface discoloration and cracking associated with conventional drying methods are also avoided.

Increases in acidity after dehydration was due to concentration of soluble, however the handling during pretreatments likes 1 per cent $CaCl_2$ dip, 2 per cent sodium bicarbonate and steam blanching leads to loss of soluble (Table 1, 2 and 3)

Table 1. Drying characteristics of dehydrated vegetables

Parameter	Carrot	Cabbage	French bean
Dehydration time (min)	180	120	180
Dehydration ratio (D_R)	8.6	13.17	9.54
Rehydration time (min)	120	120	120
Rehydration ration (R_R)	5.78	8.38	6.76
Coefficient of dehydration	0.68	0.94	0.68

Each value was average of three determination

Table 2. Quality parameter of dehydrated vegetables

Sample	Parameters	Fresh	Dehydrated
French bean	Chlorophyll (mg/100g)*	3.19	3.08
	Acidity on fresh basis	0.03%	0.14%
Cabbage	Chlorophyll (mg/100g)*	3.03	2.96
	Acidity on fresh basis	0.05%	0.20%
Carrot	Carotene (mg/100g)*	3.47	2.64
	Acidity on fresh basis	0.16%	0.64%

*Values are considered on dry weight basis

Table 3. Coefficient of rehydration of vegetables

Vegetable	Coefficient of rehydration
Carrot	0.68
Cabbage	0.94
French bean	0.68

Conclusion:

In this present work selected vegetables *i.e.* carrot cubes, cabbage and French bean were dried using radio frequency drying method. Dehydrated vegetables may be used as ingredients for salad mix, soup mix or curries after rehydration. In view of hygroscopic nature of dehydrated product, it is recommended that it is packed in laminated pouches preferably under vacuum to retain quality.

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Received : *August, 2010;* **Revised:** *April, 2011;* **Accepted :** *May, 2011*