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Effect of Osmotic Pretreatments on Properties of some Dried Garlic Products

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ABSTRACT

Garlic is one of the most important vegetable crops, but there is a loss reached approximately to 30 % of the garlic crop during storage as affected by respiration and microbial spoilage. The drying process of vegetables is one of the most commonly preservation methods used to improve food stability .The objective of this work was to decrease moisture content of garlic slices (Balady and Chinese varieties) using osmotic dehydration treatments and investigate their effect on characteristics of the end dried products. The different osmotic dehydration treatments include dipping in sodium chloride solution 250 g / L, sucrose solution 600 g / L, mixtures of sucrose solution and sodium chloride solution by 3 : 1 v/v and 3 : 2 v/v respectively for different periods (60 min, 90 min and 120 min). Moisture content results indicated that the best osmotic dehydration solution was sodium chloride at 120 min. which used only before complete drying by oven at 60 C° to produce garlic products (Paste , Cubes, and powder) for both varieties. Some chemical characteristics for fresh, osmotic treated and the end dried products were determined (such as moisture, ash, PH, oil, NaCl, and polyphenols) as well as, sensory properties of garlic products (color, aroma, taste, appearance and overall acceptance) were evaluated. The local appetizer prepared using garlic powder recorded the highest values of organoleptic characteristics comparing with those prepared using fresh and other garlic dried end products .Color change was evaluated after osmotic dehydration treatments and for end garlic products compared with fresh garlic .Also the composition of organic sulfur compounds present in extracts of fresh and garlic products were studied using gas chromatography and mass spectrometry.

Key words: Garlic, *Allium sativum*, storage, osmotic dehydration

Introduction

Many of the spices and herbs (such as garlic) used today were known to people of the ancient cultures throughout the world, and they were valued for their preservative and medicinal powers as well as their flavor and odor qualities (Zaika, 1988).

Garlic (*Allium sativum*) is used for seasoning of foods because of its typical pungent flavor. It is usually used without doing any preprocessing operation. More recently, it has found uses in its dried form, as an ingredient of precooked foods and instant convenience foods including sauces, gravies, and soups, this led to a sharp increase in the demand of dried garlic.

Egypt occupies the fourth place among the nations of the global production of garlic crop, according to UN Food and Agriculture Organization FAO statistics garlic producers (2013).

Garlic is Semi – perishable vegetable spice and nearly 30 % of the crop is wasted due to respiration, microbial spoilage during storage (Anonymous, 1993). Drying fruits and vegetables is an important mean of enhancing resistance to degradation due to the decrease in water activity (uW). Easier processing, lower transport costs as well as quality enhancements can also be achieved (Mazza and Le Maguer, 1980)

Garlic is known to possess a vast variety of biological functions. such as antimicrobial (Krest *et al*., 2000 and Kim, 2002), antithrombotic (Block *et al*., 1986), anticancer (Lawson, 2000), and antioxidant (Wu *et al*., 2001), and could improve the immune system (Kang *et al*., 2001), as well as had the capacity to lower serum lipid and glucose levels (Krest, 2001) and blood pressure (Sovova, 2000).The physiological effects of garlic are mainly due to the presence of volatile sulfur compounds like thiosulfates which give pungent aroma (Agarwal, 1996)

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Increased drying temperature entails higher costs and may cause biochemical changes that degrade the dried product quality; whereas subdividing the material is an additional process that results, (especially under industrial conditions), in mass losses and lowering of the product quality (Watada *et al*., 1996). The texture of a dried material is usually estimated using compressive strength tests (Lewicki and Jakubczyke, 2004). It turns out that rehydration of a dried material may furnish valuable information on the material structure fixed by drying (Witrowa-Rajchert, 1999). In the case of garlic, a color alteration and reduction in volatile oil may also be of interest.

Osmotic dehydration is a process of partial removal of water by soaking foods, mostly fruits and vegetables in hypertonic solutions (Shi and Maguer, 2002)

Osmotic dehydration is a gentle way of removing water from plant tissues such as fruits or vegetables. Osmotic dehydration is carried out by immersion in a hypertonic solution. The movement of moisture from the product to the osmotic solution is governed by the difference in osmotic pressures. Not only the moisture is removed from the product but also diffusion from the hypertonic solution into the product (Lombard *et al*., 2008)

Leakage of natural solutes from plant tissue occurs because the cell membranes of plant tissue responsible for osmotic transport is not perfectly selective but this flow is negligible, although it may be important for the organoleptic and nutritional properties of the product (Mizrahi *et al*., 2001). The main compounds responsible for flavor in garlic are mostly sulfur-containing, non-volatile amino acids (thiosulfinates), among which alliin or S-allyl-cysteine sulfoxide (ACSO) is the most predominant garlic flavor precursor (Hornícˇková *et al*., 2010) Volatile organ sulfur compounds (e.g. alk(en)yl (poly)sulfides) were provenance to be biologically active and had been shown to affect human health (Tapiero *et al*., 2004).

This work aims to decrease moisture content of garlic slices (Balady and Chinese varieties) using osmotic dehydration treatments and investigate their effect on characteristics of the dried end products

Materials and Methods

Plant material:

Garlic cultivars (Balady and Chinese) planted in EL-Maghara Research Station - Desert Research Center in (North Sinai - Egypt)

Chemicals and reagents:

All Chemicals and reagents were purchased from El-Gomhoria Co. Cairo, Egypt.

Osmotic dehydration treatments:

Garlic cloves, were peeled and hand cut into two or three segments and then divided into four parts every part was dealed with one of the following osmotic dehydration solutions

1. Sodium chloride solution (250 gram / liter)
2. Sucrose solution (600 gram / liter)
3. Mixture of sucrose solution (600 gram / liter) and sodium chloride solution (250 gram / liter) by3:1v/v.
4. Mixture of sucrose solution (600 gram / liter) and sodium chloride solution (250 gram / liter) by 3 : 2 v/v

The osmotic dehydration treatments carried out at different periods (60 – 90 -120 minutes). The lowest moisture content of osmotic dehydration treatment was blended and divided into three parts as follow:

-The first part was partially dried at 60 C° till the moisture reached less than 35% and then packed in glass jars of 100 grams capacity and sterilized at 100 ° C for 20 minutes to produce garlic paste.

-The second part was placed in the cubes on drying trays and dried at 60 ° C till the moisture reached less than 12% to produce dried garlic cube, and then wrapped with aluminum foil

-The third part was placed on drying trays and dried at 60 ° C till the moisture reached less than 4% in the final product to produce dried garlic powder product, and then packed in glass jars of 100 grams

Chemical analysis:

- Sodium chloride, ash, oil and Moisture contents were determined according to the AOAC (1990)

-Polyphenols: were estimated as total polyphenols using the method described in the AOAC (1970).

Color:

The chromaticity of the dried garlic cloves was measured in terms of L (the degree of the lightness), a (degree of redness) and b (degree of yellowness) values, using a Hunter Lab Colorimeter. The colorimeter was calibrated against a standard calibration plate of a white surface with L, a, b values of 91.10, _0.64 and _0.43, respectively. The measurements of color were replicated five times after shaking the dried samples and the average values of L, a, and b were reported the shaking was primarily done to take into account. The variation in the color with the orientation of garlic cloves, if any in the sample.

Determination of the essential oil:

Essential oil percentage (ml / 100 g) of each sample was determined with hydro-distillation for 3 hours at Clevenger-type apparatus using 20 g of fresh and garlic products according to the Egyptian Pharmacopoeia (1984). The resulted essential oil of each treatment was separately dehydrated with anhydrous sodium sulphate and kept in the deep freezer until GC-MS analyses.

GC-MS analysis:

The GC-Ms analysis of the essential oil samples was carried out using gas chromatography-mass spectrometry instrument stands at the Department of Medicinal and Aromatic Plants Research, National Research Center with the following specifications .

Instrument: a TRACE GC Ultra Gas Chromatographs (THERMO Scientific Corp., USA), coupled with a THERMO mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). The GC-MS system was equipped with a TG-WAX MS column (30 m x 0.25 mm i.d., 0.25 µm film thickness). Analyses were carried out using helium as carrier gas at a flow rate of 1.0 ml/min and a split ratio of 1:10 using the following temperature program: 60 ° C for 1 min; rising at 3.0 ° C /min to 240 ° C and held for 1 min. The injector and detector were held at 240 ° C. Diluted samples (1:10 hexane, v/v) of 0.2 µL of the mixtures were always injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of m/z 40-450. Most of the compounds were identified using the analytical method: mass spectra (authentic chemicals, Wiley spectral library collection and NSIT library).

Sensory evaluation of product:

The final garlic products as well as fresh garlic were used in preparing a local appetizer, which consists of :

- 40 g garlic (on the dry basis)
- 200 g Mayonase
- 3g vinegar
- 2 g Citric acid
- 400 g potatoes
- 10 g salt

- 100 g water

The obtained appetizer was sensory evaluated by ten semi trained panel judges. The samples were evaluated at room temperature and under cool white fluorescent lighting. The panelists were asked to assess the samples for color, taste, appearance, aroma and overall acceptability on a 9-point hedonic scale. Cabezudo, (1982).

Statistical analysis:

All determinations were carried out in triplicate and data is reported as mean. Significant differences (p<0.05) were calculated using Duncan's multiple range test, followed the method reported by Steel and Torrie (1980).

Results and Discussion

Results data in table (1) showed that, all studied osmotic treatments led to decrease the moisture content comparing to fresh sample either for Balady or Chinese varieties. Where, the lowest moisture contents were recorded for the samples treated by dipping in Na Cl for different periods either for Balady or Chinese varieties.

Also the tabulated data in table (1) illustrated that, the higher the dipping time the lower the moisture content for all studied osmotic treatments either for Balady or Chinese varieties.

Table 1: Effect of different osmotic treatments for different periods on the moisture content of garlic slices of (Balady and Chinese) varieties

Var.	Time	Fresh	NaCl 250g/L	Sucrose 600g/L	NaCl:Sucro. 1:3 v/v	NaCl:Sucro. 2:3 v/v
		Moisture%				
Balady	60 min	62.43 %Aa	55.33 %Ae	59.93 %Bb	58.20 %Ac	57.00 %Ad
	90 min		53.42 %Ce	57.84 %Cb	56.6 %Bc	55.21 %Cd
	120 min		51.66 %Dd	55.00 %Eb	54.01 %Ebc	53.30 %Cc
Chinese	60 min	63.22 %Bb	54.94 %Be	61.22 %Ab	57.2 %Bc	56.32 %Bd
	90 min		50.21 %Ee	58.61 %Cb	55.8 %Cc	54.20 %Dd
	120 min		47.14 %Fe	56.02 %Db	54.94 %Dc	53.62 %Ed

Values bearing the same capital superscript within the same column are not significantly different (P> 0.05)
Values bearing the same small superscript within the same row are not significantly different (P> 0.05)

From the presented data in table (1) it could be noticed that the lowest moisture content (47.14 %) was recorded for Chinese garlic slices which treated by dipping in Na Cl (250g/ L) for 120 min, while the highest moisture content was recorded for Chinese garlic slices which treated by dipping in scurose (600/L) for 60 min in comparison with other studied treatments except fresh samples which had moisture content 62.43% and 63.22% for Balady and Chinese varieties, respectively. These results were similar with those reported by Benkeblia (2007) who found that moisture content of garlic ranged between (60 – 70%).

The previous results showed that the best osmotic dehydration solution treatment was Sodium chloride solution (250 gram /liter) at 120 min by estimating the loss in moisture of treated garlic,

From data presented in table (2) it could be observed that osmotic treatment led to decrease moisture, oil, volatile oil and polyphenols contents comparing to fresh sample of Balady variety ,while ash and Na Cl contents increased.

On the other hand, drying processes on 60 ° C led to increase oil, ash, Na Cl and polyphenols contents of Balady variety products. Only v. oils decreased after drying processes this may be due to the effect of heat on evaporation of v. oil.

Regarding to Chinese variety, the same situation of Balady variety was observed, where osmotic treatment led to decrease oil, v. oli and polyphenol contents, while ash and Na Cl contents increased. Also drying process led to increase oil, ash, Na Cl and polyphenols contents for Chinese variety products. Only v. oil decreased after drying processes this may be due to the effect of heat on evaporation of v. oil.

Table 2: Chemical characteristics of fresh, osmotic treated garlic slices and garlic end products of Balady and Chinese varieties

Balady											
Ch. Pro. / Treat.	Moisture	Oil %	V. Oil%	Ash%	NaCl	PH	P.phe.	Color parameters			
								H°	b*	a*	L*
Fresh	62.43%a	0.56%e	0.165%a	3.57%e	0.72e	6.10a	2.51c	74.43e	35.6a	1.48d	68.1d
A.O.T	53.30%b	0.48%d	0.155%b	4.96%d	1.37d	5.70b	2.18d	76.84c	32.4c	1.43e	79.3a
Pastes	31.94%c	0.58%c	0.078%c	6.20%c	1.59c	4.30c	2.51c	84.72a	31.1e	2.28b	77.4c
Cubes	11.42%d	0.71%b	0.081%c	7.90%b	1.88b	3.44d	2.88b	75.43d	32.8b	2.16c	78.1b
powder	4.32%e	0.92%a	0.078%c	9.33%a	2.18a	3.01e	3.25a	81.73b	31.7d	2.54a	79.4a
Chinese											
Ch. Pro. / Treat.	Moisture	Oil %	V. Oil%	Ash%	NaCl	PH	P.phe	Color parameters			
								H°	b*	a*	L*
Fresh	63.22%a	0.43%d	0.148%a	2.90%e	0.78e	6.22a	2.15c	73.05e	30.2a	1.17e	74.3e
A.O.T	53.6%b	0.32%e	0.136%b	3.79%d	1.62d	5.82b	1.90d	79.37c	30.1a	2.31c	81.3d
Pastes	34.19%c	0.55%c	0.086%c	5.75 %c	1.87c	4.50c	2.16c	87.77a	29.4b	2.37b	83.1b
Cubes	12.52%d	0.65%b	0.08%d	7.31%b	2.12b	3.84d	2.62b	78.64d	26.2c	2.49a	83.8a
Powder	4.45%e	0.85%a	0.078%d	8.29%a	2.34a	3.35e	3.20a	81.14b	25.6d	2.14d	82.9c

Values bearing the same superscript within the same column are not significantly different for each variety separately (P> 0.05)

A.O.T (after osmotic treatment) *Ch. Pro. Chemical properties* *V. oil Volatile oil* *P.phe polyphenol contents*

From the presented data in the same table it could be concluded that, garlic powder had higher shelf life comparing to other products for both studied garlic varieties, where powder had the lowest moisture content and the highest polyphenols contents.

The mentioned results were in agreement with those reported by Toledano-Medina *et al*. (2016) who noticed that pH value decreased at the end of heat treatment from 6.31 (for fresh peeled garlic cloves) to 3.8 (for dried garlic cloves) , Also they reported that the polyphenols content increased from 3.2 (for fresh peeled garlic cloves) to 4.4 (for dried garlic cloves)

Concerning to the chromaticity results of fresh, after osmotic treatment and end product samples in (table, 2) it could be noticed that, L and H values ranged from 68.1 to 84.72 for Balady garlic samples and from 74.3 to 87.77 for Chinese garlic samples this means that Chinese samples were more brightness than Balady samples ,and both of them had creamy – white color (Somkiat Prachayawarakorn *et al*. (2004)

The presented data in table (2) also showed that, osmotic treatment and drying process led to increase Brightness comparing to fresh samples either for Balady or Chinese varsities.

Also, osmotic treatment and drying process led to shifting the color towards red comparing to fresh samples (a values) either for Balady or Chinese varieties .while b values (which related to yellow and blue) indicated that, both of osmotic and drying process led to decrease the yellowness comparing to fresh samples

Table 3: Sulfur compounds of fresh, osmotic treated and the end products of Balady garlic.

Sulfur Compounds	Fresh	A.O.T	Paste	Cube	Powder
	Area%				
Diallyl sulfide	0.35	0.28	1.61	1.79	1.92
Disulfide, methyl 2-propenyl	5.12	4.50	3.55	3.05	2.49
1,2-dihydrocyclobutabenzene	0.08	0.14	0.20	0.28	0.36
Trisulfide, dimethyl	1.04	0.94	0.68	0.33	0.26
di-limonene	0.06	0.09	0.14	0.19	0.52
Diallyldisulphide	29.08	32.28	42.12	45.23	46.51
Trisulfide, methyl 2-propenyl	6.05	5.30	5.02	4.11	3.56
5-Butyl-8-methylandolizidine	0.08	1.27	0.73	0.35	0.35
2-(Mercaptomethyl)-5-methylthiophene	0.33	0.43	0.32	0.16	0.15
3-Vinyl-1,2-dithiacyclohex-5-ene	1.01	1.38	1.57	0.74	0.97
Trisulfide, di-2-propenyl	56.80	53.39	44.06	43.77	42.91

A.O.T after osmotic treatments

The effect of osmotic treatment and drying process on sulfur compounds of garlic was determined and the obtained results were tabulated in tables (3 and 4)

The presented data in table (3) showed that the dominant sulfur compounds of Balady garlic slices were Trisulfide, di-2-propenyl (56.80%) followed by Diallyldisulphide (29.08 %) then Trisulfide, methyl 2-propenyl(6.05%) and Disulfide, methyl 2-propenyl (5.12%).

Osmotic treatment led to a decrease in most sulfur compounds except Diallyldisulphide which increased. On the other hand, drying process led to increase Diallyl sulfide and Diallyldisulphide while all trisulphide compounds decreased as a result of drying process.

Table 4: Sulfur compounds of fresh, osmotic treated and the end products of Chinese garlic

Sulfur Compounds	Fresh	A.O.T	Paste	Cube	Powder
	Area%				
Diallyl sulfide	0.13	0.32	1.18	2.36	2.45
Disulfide, methyl 2-propenyl	0.74	0.47	1.35	1.44	1.73
1,2-dihydrocyclobutabenzene	0.08	0.23	0.36	0.35	0.57
Di-lemonene	0.09	0.07	0.06	0.20	0.27
Diallyldisulphide	29.06	30.09	42.41	44.87	45.90
Trisulfide, methyl 2-propenyl	5.28	4.42	3.86	3.37	3.15
5-Butyl-8-methylandolizidine	0.08	0.08	0.20	0.39	1.17
2-(Mercaptomethyl)-5-methylthiophene	0.27	0.61	0.53	0.29	0.16
3-Vinyl-1,2-dithiacyclohex-5-ene	0.88	3.74	1.69	1.20	0.86
Trisulfide, di-2-propenyl	63.39	59.97	48.36	45.53	43.74

.A.O.T after osmotic treatments

Tabulated data in table (4) showed obviously that, the highest sulfur compound of fresh Chinese garlic was Trisulfide, di-2-propenyl (63.39 %) followed by Diallyldisulphide (29.06%), then Trisulfide, methyl 2-propenyl (5.28).

From the same table, it could be noticed that, osmotic treatment led to increase Diallyldisulphide, 3-Vinyl-1,2-dithiacyclohex-5-ene and other minor components,while Trisulfide methyl 2-propenyl and Trisulfide, di-2-propenyl were decreased.

On the other side drying process resulted in decreasing of Trisulfide, di-2-propenyl.Trisulfide, methyl 2-propenyl and 3-Vinyl-1,2-dithiacyclohex-5-ene while Disulfide, methyl 2-propenyl and all minor compounds increased .

From the presented data in table (3 and 4) it could be observed that, Balady garlic contains one sulpher compound more than Chinese garlic this compound is Trisulfide, dimethyl this may be the reason of interested flavor of Balady garlic more than that of Chinese garlic.

These results were in agreement with those reported by Sowbhagya, *et al*. (2009) who found that Di-2 propenyl trisulfide was the major sulfur compound in garlic slices. Also Gregrova *et al*. (2013). reported that main sulfur compounds are un stable (when exposed to air or elevated temperatures) and degrades into various sulphur compounds after volotial ones (mono, di, and trisulphide).

Sensory Evaluation:

Sensory evaluation is the most important factor that determines consumer acceptance. Where, he always interests in good appearance, attractive color, firm texture and good organoleptic qualities of a foodstuff more than the nutritive and biological value.

Color and flavor strength have been reported to be important quality attributes for dehydrated garlic products from the consumer's acceptance point of view. (Sharma and Prasad, 2006)

Sensory properties of local appetizer produced using either fresh or different garlic products (Balady and Chinese varieties) which treated by osmotic treatments and completely dried in oven at 60 ° C were evaluated and the results were presented in Table (5).

From the presented data in table (5) it could be noticed that, the highest values of all studied sensory attributes were recorded for powder sample followed by fresh sample (either for Balady or Chinese varieties) comparing to the other studied sample, with two exceptions related to appearance and overall acceptability, where the lowest values of appearance recorded for fresh samples (either for Balady or Chinese varieties).

Table 5: Sensory properties of appetizer produced using fresh and end products of garlic varieties

Treatment / Properties	Control (fresh)		Pastes		Cubes		Powder	
	Balady	Chinese	Balady	Chinese	Balady	Chinese	Balady	Chinese
Color	7.35c	7.01e	7.28ed	6.85f	7.17d	6.94ef	8.41a	7.78b
Taste	7.12c	6.95d	6.93d	6.90d	6.98d	6.79e	7.82a	7.54b
Aroma	7.52b	7.24c	6.52f	6.42f	6.89d	6.66e	7.91a	7.60b
Appearance	6.30f	6.10g	6.68d	6.47e	6.78c	6.51e	7.21b	6.84a
Overall acceptability	7.35d	7.12f	7.33d	7.21e	7.60b	7.46c	7.79a	7.62b

Values bearing the same superscript within the same row are not significantly different (P> 0.05)

Concerning to overall acceptability results it could be noticed that, there were slight differences between fresh and paste samples. And also, there were slight differences between cubes and powder samples (either for Balady or Chinese varieties). Also, the presented data showed obviously that, Balady samples had higher values comparing to Chinese samples for all studied treatments.

Conclusion

Dipping garlic slices in sodium chloride solution (250g/ L) for 120 min, demonstrated best results of decreasing moisture content of Balady and Chinese garlic slices. The final garlic products (Pastes, Cubes and powder) for both varieties which osmatic treated had a good quality attributes and could be used in the production of different forms of dried garlic products leading that in decrease the spoliage of garlic crop.

References

Agarwal, K.C., 1996. Therapeutic actions of garlic constituents. Medical Research Reviews, 16: 111-124.

Anonymous, 1993. Project opportunities for food industry, CFRI, Mysore, India, pp: 90-93.

AOAC, 1970. Official Methods of Analysis. 11th ed., Association of Official Analytical Chemists. Washington, DC.

AOAC International, 1990. Association of Official Analytical Chemists. Official methods of analysis (15th ed.). Washington, DC.

Benkeblia, N., 2007. Phenolic Compounds of Allium Species. RRBS, 1: 135-140.

Block, E., S. Ahmad, J.L. Catalfamo, M.K. Jain and C.R. Apitz, 1986. Antithrombotic organosulfur compounds from garlic:structural, mechanistic and synthetic studies. Journal of the American Chemical Society, 108: 7045-7055.

Cabezudo, M.D., 1982. El análisis sensorial de los vinos. In Enología: Temas Actuales, ISBN: 84-300-8632-3, Asociación Nacional de Químicos de España, Madrid, Spain.

Egyptian Pharmacopoeia, 1984. General Organization for Governmental Printing Office, Ministry of Health, Cairo, Egypt, pp: 31-33.

FAO, 2013. Production and trade statistics. (Food and agriculture organization united nations Rome)

Gregrova, A., H. Čizkova, I. Bulantova, A. Rajchl and Michal Voldrich, 2013. Characteristics of Garlic of the Czech Origin, Czech J. Food Sci., 31(1): 581-588.

Horníc ková, J., R. Kubec, K. Cejpek, J. Velíšek, J. Ovesná and H. Stavelíková, 2010. Profiles of S-alk (en) ylcysteine sulfoxides in various garlic genotypes. Czech Journal of Food Sciences, 28(4): 298-308.

Kang, N.S., E.Y. Moon, C.G. Cho and S. Pyo, 2001. Immuno modulating effect of garlic component. allicin. on murine peritone almacrophages. Nutrition Research, 21: 611-626.

Kim, J.Y., 2002. Alliinase-independent inhibition of Staphylococcus aureus B33 by heated garlic. Journal of Food Science, 67: 780-785.

Krest, I., 2001. Gender may affect the action of garlic oil on plasma cholesterol and glucose levels of normal subjects. Journal of Nutrition, 131: 1471-1478.

Krest, I., J.G lodek and M. Keusgen, 2000. Cysteine sulfoxides and alliinase activity of some Allium species. Journul of Agricultural and Food Chemistv, 48: 3753-3760.

Lawson, L.D., 2000. Effect of purified allicin, the major ingredient of freshly crushed garlic, on cancer cell proliferation. Nutrition and Cancer, 38: 245254.

Lewicki, P.P. and Jakubczyke, 2004. Effect of heat temperature on mechanical properties of dried apple , Journal of Food Engineering, 50: 307- 314. Osmotic dehydration in

Lombard, G.E., J.C. Oliveira, P. Fito and A. Andrés, 2008. Osmotic dehydration of pineapple as pre-treatment for further drying. Food Engineering, 85(2): 277-284.

Mazza, G. and M. Lemaguer, 1980. Dehydration of onion some theoretical and practical consideration of Food technology, 15: 181-194.

Mizrahi, S., S. Eicheler and O. Raman, 2001. Osmotic dehydration in gel systems. J Food Eng., 49: 87-96.

Sharma, G.P and S. Prasad, 2006. Optimization of process parameters for microwave drying of garlic cloves. J Food Eng., 75: 441-446.

Shi, J. and M le. Maguer, 2002. Osmotic dehydration of foods: Mass transfer and modeling aspects. Food Rev Int., 18: 305-336.

Somkiat Prachayawarakorn; Saijai Sawangduanpen; Supranee Saynampheung Thitikorn Poolpatarachewin; Somchart Soponronnarit and Adisak Nathakarakule, 2004. Kinetics of colour change during storage of dried garlic slices as affected by relative humidity and temperature, Journal of Food Engineering., 62: 1-7.

Sovova, 2000. Effect of allicin from garlic powder on serum lipids and blood pressure in rats fed with a high cholesterol diet. Prostaglandins Leukotrienes and Essential Fatty Acids, 62: 253-259.

Sowbhagya, A.H.B., T. Kaul Purnima b.; Suma P. Florence a. A.G. AppuRao b, P. and Srinivas, 2009 Evaluation of enzyme-assisted extraction on quality of garlic volatile oil, Food Chemistry, 113: 1234-1238.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and procedures of statistics. London: McGraw Hill

Tapiero, H., D. Townsend and K. Tew, 2004. Organosulfur compounds from Alliaceae in the prevention of human pathologies. Biomedicine and Pharmacotherapy, 58: 183-193.

Toledano-Medina, M., a. Angeles, a. Pérez-AparicioJesús, b. Moreno-Rojas Rafael and Merinas-Amo Tania, 2016. Evolution of some physicochemical and antioxidant properties of black garlic whole bulbs and peeled cloves J. of Food Chemistry, 199: 135-139.

Watada, A.E., Ko, N.P. and D.A. Minott,1996. Factors affecting quality of fresh-cut horticultural products. Postharvest Biology and Technology, 9: 115-125.

Witrowa. Rajchert, D., 1999. Rehydration as an Index of Changes Occurring in Plant Tissues During Drying (in Polish). Academic Press, Rozwoj SGGW, Warsaw Poland., p: 80.

Wu, C.C., L.Y. Sheen, H.W. Chen, S.J. Tsai and C.K. Lii, 2001. Effects of organosulfur compounds from garlic oil on the antioxidation system in rat liver and red blood cells. Food and Chemical Toxicology, 39: 563-569.

Zaika, L.L., 1988. Spices and herbs: Their antimicrobial activity and its determination. Journal of Food Safety, 9: 97-118.