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Paprika color quality: Effect of air and natural drying treatments

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RESUMEN

Calidad del color del pimentón: Efecto de los tratamientos de secado al natural y al aire.

Bajo procesos de secado al natural y al aire se han investigado el color, la formación de compuestos de pardeamiento y los carotenoides totales como indicadores de la calidad del pimentón. Los datos obtenidos a partir de experimentos de secado al aire mostraron una relación inversa entre el aumento de la temperatura (40, 60 y 80° C) y la calidad del pimentón. En muestras secadas al natural, se llevaron a cabo tres tratamientos diferentes (sol, secado en la oscuridad y decolorado + secado al sol). Los datos revelaron un comportamiento irregular caracterizado por dos estados: el primero es biosintético y el segundo es degradativo con un efecto más profundo en la luz que en la oscuridad.

El análisis de los datos por regresión multilinear fue también empleado para simular los resultados, especialmente los cambios en carotenoides totales como una función del tiempo.

La evaluación sensorial para el color de las muestras indicó una larga variación en respuestas de los panelistas. Se recomendaron tratamientos a baja temperatura para favorecer la calidad del pimentón si es reducida la velocidad de formación de compuestos de pardeamiento.

PALABRAS-CLAVE: Color (calidad) – Pimentón – Secado al aire – Secado al natural.

SUMMARY

Paprika color quality inview of air and natural drying treatments.

Color, browning compounds formation and total carotenoids as indicator of paprika quality were investigated under air and natural drying processes. The data resulted from air drying experiments showed an inversely relationship between the progress in temperature (40, 60 and 80° C) and the paprika quality. In natural dried samples, three different treatments were carried out (sun, dark drying and blanching + sun drying). The data revealed an irregular pattern characterized by two stages: 1 st one is biosynthetic and the second is degradative with more profound effect in light more than darkness.

Multilinear regression data analysis was also employed to simulate the results especially the changes in total carotenoids as a function of time.

Sensory evaluation for color of the samples indicated a large variation in responses of panelists. Low temperature treatment was recommended to favour the quality of paprika if the rate of forming browning compounds is reduced.

KEY-WORDS: Air drying – Color (quality) – Natural drying – Paprika.

1. INTRODUCTION

Red pepper fruits (Capsicum annum L.) are widely cultivated in many countries e. g. Spain, Turkey, Hungary, United States and Egypt. These fruits are used for preparing various dehydrated products, such as ground pepper (paprika), red pepper flakes and oleoresin (solvent extracted fraction from the fruits).

The principal coloring component of paprika is the carotenoid pigment capsanthin. The outer fleshy pericarp carries the major portion of the coloring matter, while the inner tissues and seeds contain the pungent chemical (capsaicin). High color value paprika is prepared by grinding only the fruit pods, whereas low-color paprika is prepared by grinding the pods containing seeds. The seeds decrease the overall color value of the spice (Farrell, 1990).

Forthcoming regulations will tend to restrict the use of foodstuff colorants exclusively to natural compounds, while artificial compounds will disappear progressively from the lists of acceptable colorants (Chambolle, 1992). Therefore, it will be necessary to evaluate the processing steps that affect the nature of these coloring matters so that the industry can develop profitable processes with homogenous stable and safe products.

As paprika is usually used for its color, enhancing qualities, it is suitable for use in seasoning for frankfurters, minced-meat specialities and some sausage products. Paprika is also used in the manufacture of tomato sauces and Mexican chili powder. It is also used in condiments, baked goods, confections, soup, salad dressings, frozen desserts and pickled products (Farrell, 1990).

The sequence of industrial operations (drying, grinding & storage) of paprika may destroy part of the components initially present in the fruit, in particular the fraction including the carotenoid pigment which is responsible for the commercial quality of the product. The main parameter used for commercial evaluation of paprika quality is the color which is affected to a high degree by the amount and distribution of carotenoid pigments. The two used methods in industry for evaluating the color are ASTA-20 and STANDARD, and although the value given by each is different for the same sample, the correlation between measurement is good (Salmerón Salmerón, 1973).

Reinecke *et al.,* 1995 have attributed the changes in paprika color to two major categories:

Non enzymatic reactions:

– Autoxidation: Oxidative processes starting during heating and later by the presence of highly unsaturated oils (Kanner *et al.,* 1976, 1977).

– Maillard reaction.

– Thermal and mechanical stress: The increase of surface due to milling may cause significant loss of pigments and stability of the final products.

Enzymatic reactions:

– Food enzymes: peroxidase, polyphenoloxidase.

– Microbial enzymes.

From the nutritional point of view, the importance of the carotenoid compounds in the diet has been recognized in recent years, some of them have provitamin A activity. Red pepper is one of vegetables that has a high content of provitamin A due to high concentration of β-carotene and β-cryptoxanthin (Simpson, 1983).

The appearance of some types of cancer has been associated with the lack of certain oxygenated carotenoids in the diet which are considered to be anticancer compounds (Moon and Atri, 1984).

Other studies have reported antiulcer properties manifested by the carotenoid compounds acting as protectors of gastric mucosa (Javor *et al.,* 1983).

The aim of the present work was to investigate, as possible, the relationship between paprika color, browning compounds formation and total carotenoids (as quality attributes) during some air and natural drying treatments. Sensory evaluation was carried out in the present investigation to prope the consumer acceptability towards the different treatments of paprika products. Comparative study was also conducted between the evaluation of color quality of paprika by instrumental analysis and sensory evaluation.

2. MATERIAL AND METHODS

Selection and preparation of samples: Red pepper fruits (Capsicum Annum var. California Wonder) were obtained from Agricultural Research Center, Horticulture Dept., Dokki, Giza, Egypt. The fruits were selected carefuly and harvested in red mature stage. Any samples showed abnormalities were rejected.

Samples were collected, washed, deseeded and sliced to small pieces removing all the green parts. The resulted samples were subjected to the following drying treatments:

– Oven drying at 40, 60 and 80° C.

– Natural drying: sun drying, dark drying and blanching + sun drying (blanching was carried out in hot water at ~100°C for 30 min.).

The product of each treatment was ground and reserved in a tidely sealed bage.

Sampling: Samples of fresh and dry fruit were taken randomly for analysis. The oven and natural dried samples were taken at different time intervals according to the progress in drying i.e. (stability in the moisture content). Moisture content was estimated according to (A.O.A.C., 1990). The different moisture contents in the samples during processing make it necessary to refer the pigment concentration to the dry matter to make the results comparable.

Extractable color: Paprika color was measured according to American spice trade association (ASTA, 1990).

Total carotenoids and browning compounds formation were detected as described by (Ramakrishnan and Francis, 1973). The total carotenoids were calculated as β-carotene using $E^{1\%}_{cm}$ = 2500 at absorbance 450 nm. The colored browning compounds were reported as absorbance units calculated as absorbance at 450 nm x dilution factor.

Sensory evaluation for paprika color: The panelists were asked to rate the samples for their saturation, lightness and visual quality on a score card. Quantitative descriptive analysis (Stone *et al.,* 1974) was used to quantify the precieved responses.

– Saturation refered to the intensity of color represented by high or low extreme ends of the scale.

– Lightness refered to the extent of gray in the color with dark light defining the extremes of the rating scale.

– Visual quality of the product related to the overall judgment based on color and appearance of the product.

Moisture change during drying: Fick's law was used to study the kinetic of moisture change during air drying. The moisture changes were described in the first falling rate period (Saguy *et al.,* 1980).

$$E = \frac{m - m_e}{m_i - m_e} = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \cdot \exp\left[-\frac{\pi^2 (2n+1)^2}{L^2} Dt\right] \quad \dots (1)$$

for $E \leq 0.6$ eq (1) reduces to:

$$E = \frac{8}{\pi^2} \exp\left(-\pi^2 \, Dt / L^2\right) \quad \dots \qquad (2)$$

Where:
E = fractional moisture ratio
m = mean moisture at time t (hr).
L = slab thickness (cm).
m_i = initial moisture %.
m_e = moisture equilibrium.
D = Diffusion coefficient (m^2/s).

The diffusion coefficient (D) may be expressed by a general Arrhenius-type equation:

$D = D_O \exp(-E_a/RT)$

Where:

D = frequency factor (m^2/S).

E_a = Activation energy (cal/mol).

R = Gas constant (1.987 cal/mol. K^O).

T = Absolute temperature (K^O).

Pigment losses during drying:

Multiple regression analysis was used to quantify the relationship between pigment loss (total carotenoids/kg dry weight) and drying time in both of sun and air drying. Variables equated in multiple regression models included drying time, drying time squared in case of air drying in addition to cubic drying time in case of natural dried samples (in sun and in dark). The data were fitted to the models and slopes were calculated using the statistical analysis system (SAS, institute Inc., 1985) software.

3. RESULTS AND DISCUSSION

Table I illustrated the changes in dry matter, total carotenoids, browning compounds and ASTA values of paprika samples when heated in air-drying oven at (40, 60 and 80°C). From the obtained results it was observed that:

– Upon drying at 40°C for 130 hrs the treated samples contained 95.11% dry matter. The same results was nearly obtained when the drying was carried out at 60°C (drying time 42-44 hrs) and at 80°C (drying time 10-12 hrs).

– Loss % of total carotenoids of the sample dried at 40°C for 130 hr reached 11.21, whereas approximately same values of the latter % were obtained upon drying at 60 and 80°C for 24-36 hrs and less than 6 hrs, respectively. The tabulated data cleared also that almost 40.41% decrease in ASTA values occured at 40°C for 130 hrs drying time, at 60°C for 24-36 hrs and at 80°C for less than 6 hrs drying time respectively.

– The browning compounds were formed at minimum level of 28.82% upon drying the treated samples at 40°C for 130 hrs, whereas, the same result was obtained for drying at 60 and 80°C for 24-36 hrs and less than 6 hrs respectively. Also, when paprika samples were oven-dried at 80°C it was observed that the browning compounds formation increased gradually to reach 91.22% at 13 hrs of drying (with a highest rate of 3.851 hr^{-1}; c. f. table II). The loss of total carotenoids and ASTA percentages were also found to be increased to reach 30.84 and 88.33 respectively.

Table I
Changes in total carotenoids, browning compounds and carotene destruction as a function of time during paprika drying in air drying oven

Treatments	Drying time (hr.)	Dry matter %	Total carotenoids		Browning compounds		ASTA*	
			mg/kg dry wt.	Loss %	Abs x dil	increase %	Value	destruction %
Fresh	0	13.73	321	–	52.4	–	240	–
40° C	24	70.32	318	0.93	53.7	2.48	205	14.58
	48	84.33	316	1.55	54.7	4.39	200	16.66
	72	86.26	300	6.54	55.1	5.15	170	29.16
	96	88.70	298	7.17	56.3	7.44	167	30.41
	120	89.60	293	8.72	57.1	8.96	149	37.91
	125	92.60	290	9.66	59.2	12.98	146	39.16
	128	93.10	289	9.97	62.4	19.08	144	40.00
	130	95.11	285	11.21	67.5	28.82	143	40.41
60° C	12	69.02	315	1.86	60.7	15.84	194	19.16
	24	74.40	313	2.49	65.7	25.38	186	22.50
	36	91.20	280	12.77	81.1	54.77	119	50.41
	42	94.20	277	13.71	82.7	57.82	117	51.25
	44	97.70	274	14.64	83.8	59.92	110	54.16
80° C	6	75.30	274	14.64	74.6	42.36	100	58.33
	10	92.60	226	29.59	93.2	77.86	46	80.83
	12	96.40	224	30.21	99.7	90.26	30	87.50
	13	97.70	222	30.84	100.2	91.22	28	88.33

* Color evaluation method.

From the above mentioned observations it can be indicated that there was a clear relation between moisture content, total carotenoids, ASTA and browning compounds formation in affecting oven-dried paprika color quality.

Fig. 1 showed a degradative pattern in total carotenoids as influenced by drying time, and followed a first order reaction rate. This calculated rate was found to be of low value in case of drying at 40°C (1.678×10^{-4}) and of high value in case of drying at 80°C (5.718×10^{-3} hr) as shown in table II.

Low drying rate gave superior color quality. This observation has been previously found and idealized by (Minguez-Mosquera *et al.,* 1994) who stated that high degree of dehydration reached; the rheology of the product and the high concentration of pigment, give paprika with a dark earthy appearance and has been also confirmed by (Zapata *et al.,*1992) who suggested as a general rule that the temperature should not exceed 50-60°C with less than 50 hrs drying period.

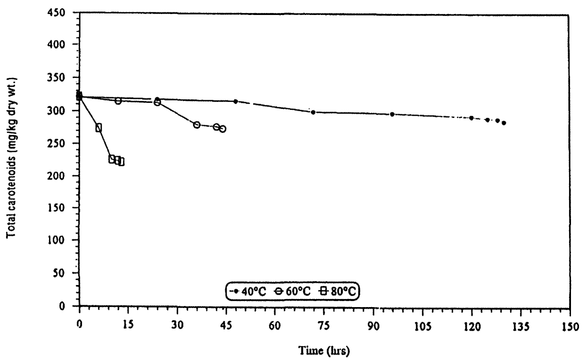

Figure 1
Changes in total carotenoids as a function of time during paprika drying in air drying oven

Changes in paprika quality as a function of dry matter, total carotenoids, browning compounds and ASTA values during natural drying treatment (sun, dark and blanching+sun drying) were presented in table III. The dry matter % was found in the range 95.71-96.78 for the three used treatments for drying at the applied maximum time period (288 hrs). With respect to the total carotenoids changes (synthesis and degradation), it was observed that these changes were irregular by time during both sun and dark treatments.

The rate of total carotenoids synthesis or degradation could be divided into two phases; as shown from fig. 2. 1st phase was characterized by an increase in total carotenoids as time proceeded reaching its maximum at 72 hrs (433 mg/kg dry weight). This phase was clearly observed in the sun dried than the dark dried samples since the latter treatment took a longer time to reach its maximum at 144 hrs (330 mg/kg dry weight). 2nd phase was also noticed in both sun and dark dried samples. It was marked by a decline in total carotenoids reaching its stability at 144 and 168 hrs, respectively.

In case of blanching + sun drying treatment the carotenoids percentages were generally found of degradative order till 168 hrs of drying (163 mg/kg dry weight), then reached 170 mg/kg dry weight at 288 hrs of drying (table III and fig. 2).

Minguez-Mosquera *et al.,* 1994 have found that some changes in the pigment content during natural drying treatment don't follow a degradative pattern as would be expected in case of air drying treatments.

When drying of the fruits is carried out slowly the synthesis of carotenoids takes place together with degradations induced by external factors. Nevertheless with fast drying (air drying), the biosynthetic reactions don't exist and only the degradative losses are apparant, that is why the changes in the industrial drying can follow zero or first order reaction rate; but during slow drying it can't be explained using one single kinetic pattern.

Table II
Paprika calculated dif. coef., rate of total carotenoids degradation and of browning compounds formation during air and natural drying treatments.

	Air drying			Natural drying		
	40	60	80° C	Dark	Sun	Blanching + sun
Diffusion coefficient (m^2/S)	3.552×14^{-13}	1.3088×10^{-12}	8.367×10^{-12}	4.84×10^{-13}	9.63×10^{-13}	3.67×10^{-13}
Rate of total carotenoids degradation (hr^{-1})	1.678×10^{-4}	7.394×10^{-4}	5.718×10^{-3}	–	–	–
Rate of browning compounds formation (hr^{-1})	0.0784	0.743	3.851	0.185	0.3194	0.221

Activation energy of the whole process 17.259 cal./mol.

Table III
Changes in total carotenoids, browning compounds and carotene destruction as a function of time during paprika natural drying treatments

Treatments	Drying time (hr.)	Dry matter %	Total carotenoids mg/kg dry wt.	Total carotenoids decrease or increase %	Browning compounds Abs x dil	Browning compounds increase %	ASTA*
Fresh	0	13.73	321	–	52.4	0	240
Dark drying	24	29.72	277	13.71	55.5	5.92	245
	48	49.72	305	4.98	80.0	52.67	246
	72	56.62	289	0.97	87.7	67.37	244
	96	69.52	309	3.74	93.6	78.62	250
	120	84.52	284	11.53	97.5	86.07	244
	144	91.56	330	2.80	99.5	89.89	255
	168	93.42	329	2.49	102.6	95.80	230
	288	95.71	331	3.11	104.6	99.62	270
Sun drying	24	18.92	350	9.03	58.6	11.83	245
	48	34.99	421	31.15	74.7	42.56	242
	72	40.28	433	34.89	99.8	90.46	250
	96	54.38	410	27.73	103.9	98.28	240
	120	89.52	400	24.61	110.9	111.64	238
	144	94.62	398	23.99	124.7	137.97	240
	168	95.77	407	26.79	133.2	154.19	247
	288	96.78	404	25.86	135.8	159.16	230
Blanching + sun drying	24	30.22	316	1.55	54.2	3.44	200
	48	50.77	258	19.63	70.9	35.30	100
	72	58.78	257	19.94	100.0	90.84	70
	96	64.80	250	22.12	105.6	101.53	65
	120	70.90	190	40.81	108.6	107.25	62
	144	86.70	173	46.11	113.7	116.98	58
	168	93.20	163	49.22	109.7	109.35	40
	288	96.70	170	47.04	110.2	110.31	30

* Color evaluation method.

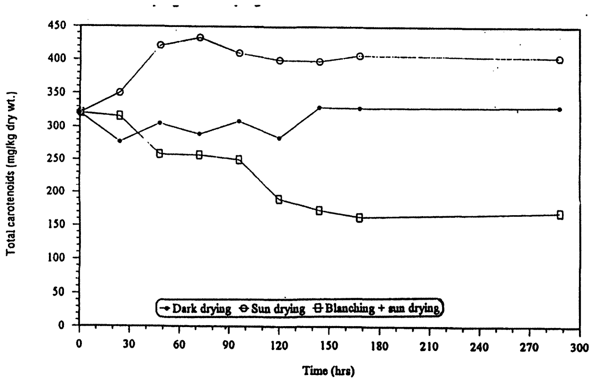

Figure 2
Changes in total carotenoids as a function of time during paprika natural drying treatments.

As was expected illumination is the greatest inducer of pigment degradation under the used conditions. Light has also a metabolic effect which is masked by its degradative effect. So, biosynthetic response of fruit under illumination is stronger in light than in darkness and this fact allows the fruit to compensate for photodegradative reactions. Thus, light plays two opposite roles i. e. as an accelerator of pigment catabolism and as inducer of degradation (Mínguez-Mosquera *et al.*, 1994).

Upon comparing the formation of browning compounds in natural drying samples, it was noticed that the data followed a zero order reaction rate. Thus the rate of browning compounds formation can be calculated (table II). This rate was found higher in case of sun dried samples (0.3194 hr^{-1}) than in case of dark dried samples (0.185 hr^{-1}). In blanched paprika samples the calculated rate of forming browning compounds was (0.221 hr^{-1}). This rate was lower than that of the sun dried samples.

Noteworthy to observe from table III that at final drying stage (96.70% dry matter), blanching effect accounted for a loss of almost (47.04%) of total carotenoids and enhanced browning compounds formation by (110.3%) and the ASTA was noticed to be of value 30 at 288 hrs of blanching+sun drying. This can emphasize the idea that blanched paprika gave more isomers and oxidative products than that of unblanched paprika (Rosalita *et al.,* 1970).

However, attention must be drawn to the unique contrasting roles of carotenoids in photochemical processes. It has been established that β-carotene function as a protective agent in plant tissues, acting as energy transducer without loss of pigment. On the other hand, carotenoids themselves function as energy absorbing species in simplex media, and with greater availability of oxygen, the pigment promote their own destruction (Carnevale *et al.,* 1980).

The entire drying process for red pepper occured during the falling rate period, when the experimental data expressed by E (as defined in Equation (1), c. f. material and methods) were plotted versus time on a semi-logarithmic coordinate, a straight line was obtained ($E \leq 0.6$) for various air drying temperatures as well as natural drying treatments (sun, dark and blanched+sun dried samples).

Linear regression was used to derive the slope of the straight line portions. These derived values may be regarded as apparent water diffusivity, which also express the structural changes in red pepper slices and must be considered also for the prediction of pigment losses during processing.

The diffusion coefficient was also found to be depended on air drying temperature and can follow the general Arrhenius type relation with 17.259 cal./mol.– activation energy. This result was found to be somewhat different from the work of (Turhan *et al.,* 1996) but such a variation could be attributed to the type of the applied drying method (tunnel drying). Diffusion coefficient (D) could be also related to the changes that occured in paprika quality during drying treatment as shown in table II. It was minimum in the blanching treatment (3.67×10^{-13}) and maximum in case of sun treated samples (9.63×10^{-13}).

Multiple regression models for the prediction of total carotenoids degradation in oven and natural drying (sun, dark and blanching+sun) were presented in table IV. Examination of the calculated coefficient of determination (R^2) indicated that drying time was largely responsible for the degradation of total carotenoids. All the regression models included nonlinear transformations of heating time because of the marginal effect (negative) of drying time on total carotenoids.

In case of air drying at different temperature levels quadric function of time was found sufficient to fit the model; but in natural drying treatment the data showed variations weither positive or negative in total carotenoids wich can't be explained using one single kinetic parameter, so that the data fitted a cubic function.

Color of paprika dried samples was introduced to sensory evaluation, the data were presented in table V. Samples that processed at 40°C gave a product with high saturation (6.4), fairly light (5.5), with good visual quality (5.9). However, paprika quality were getting worst when high temperature was employed at 80°C. It achieved a score of (4.1) saturation, (3.6) lightness and mild visual quality (4.0).

Dark and sun dried samples gave also acceptable products with better visual quality than oven-dried samples.

In view of the presently applied drying treatments for some paprika varieties the following points could be picked up as a general conclusion:

– It could control easily and in a general way the quality of red pepper by carotenoides measured as β-carotene and as ASTA.

– The rate of browning compounds formation could be considered as an indicator in affecting the quality through masking red color of paprika.

This rate was found to be directly proportional to the applied temperature i. e. high in case of sun dried than dark dried samples.

Table IV
Prediction models for oven-air, sun and dark dried paprika samples

Attribute	Prediction Equation	R^2
Oven-air dried (40°C)	$Y = 326.983 - 0.32614\ time + 0.000191\ time^2$	0.974
Oven-air dried (60°C)	$Y = 318.892 + 0.18270\ time - 0.028700\ time^2$	0.963
Oven-air dried (80°C)	$Y = 432.852 - 35.4060\ time + 1.483800\ time^2$	0.997
Blanched + sun drying	$Y = 353.189 - 1.74200\ time + 0.03810\ time^2$	0.964
Sun drying	$Y = 307.621 + 2.87200\ time - 0.021700\ time^2 + 4.490 \times 10^{-5}\ time^3$	0.776
Dark drying	$Y = 286.424 - 0.11702\ time + 0.003730\ time^2 - 9.656 \times 10^{-6}\ time^3$	0.794

Y = Total carotenoid content mg/kg dry wt.

Table V
Sensory Evaluation of Paprika Color Quality

Treatments	Saturation	Lightness	Visual quality
Drying at (40° C)	6.4	5.5	5.9
Drying at (60° C)	4.9	4.9	5.1
Drying at (80 ° C)	4.1	3.6	4.0
Sun drying	5.7	5.9	6.3
Dark drying	6.1	6.3	6.5
Blanching + sun drying	6.0	6.2	6.8

0= not noticeable 1 = trace-not sure 2 = faint 3 = slight
4 = mild 5 = moderate 6 = definite 7 = strong
8 = very strong.

– The proposed statistical models (in order to simulate the changes in total carotenoides as a function of time) predicted clearly the degradative pattern in total carotenoids with respect to the applied temperature. Air drying data fitted a 1st order reaction rate i. e. the rate of total carotenoids degradation was directly proportional to the temperature. Natural drying (sun or dark) data fitted properly to the cubic function indicating the expected occurance of some other processes (e. g. photosynthesis and/or degradative).

– Drying in the dark showed lower total carotenoids degradation than sun drying. These changes seemed better than paprika oven-drying at 40°C; but the rate of forming browning compounds was high.

Therefore, low temperature is now presented and could be recommended to favour the color quality of paprika if the rate of forming browning compounds can be reduced.

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