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Effect of Salt on Colour Degradation Kinetics of Visual Green Colour in Fluted Pumpkin (*Telfairia occidentalis*) Leaves

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ABSTRACT

The effect of common salt (0, 1, and 2% by weight) on visual green colour degradation of fluted pumpkin (*Telfairia occidentalis*) puree over a temperature range of 50–100° C was studied. Hunter colour scale values *L* (lightness), *a* (greenness or redness) and *b* (blueness or yellowness) of each treated samples were measured. The visual colour was evaluated using a Hunter lab colorimeter in terms of *L*, *a* and *b*. The results were analysed using Oakdale Engineering Datafit 8.2. The degradation of visual green colour of fluted pumpkin increased with an increase in heat treatment time and salt concentration. The degradation as measured by -*a* value followed a first order kinetics. There was consistent decrease in *L* and -*a* values with an increase in treatment time and temperature. During heat processing, the puree turned olive green and the *a* value changed from an initial value of -11.32 to -10.40, -10.73 and -10.87 at 50°C for the 0, 1 and 2% level of salt addition, respectively. The corresponding values at 100°C were -3.11, -3.65 and -3.72, respectively. There is stabilization of green colour in thermally processed fluted pumpkin puree containing salt which decreases the rate of chlorophyll degradation. The stabilizing effect of salt is not well established and no information is available on fluted pumpkin leaves, especially in term of visual colour. The paper established the stabilizing effect of salt on fluted pumpkin leaves and modelled the degradation kinetics with Arrhenius equation.

Keywords: Arrhenius equation; puree; sodium chloride; stabilization

INTRODUCTION

Green leafy vegetables are low in energy value due to high water content. Their chief nutritive significance is their richness in mineral and vitamins. Leafy vegetables contribute substantially to protein, mineral, vitamins, fibre and other nutrients which are usually in short supply in daily diets (Mosha and Gaga 1999). Fluted pumpkin (*Telfairia occidentalis*) is a green leafy vegetable. The leaf is cherished for young tender shoot and leaves. These leaves are cut at interval or when needed and eaten as pot-herbs or soup. Recently, the Yoruba of south-western Nigeria cultivate habit of preparing juice from the tender shoots of the fluted pumpkin and drink for its richness in vitamins and minerals, the seeds are boiled and eaten as nuts or ground for use in soups as thickener.

Heat treatment is one of the most widely used methods of preserving and extending the useful shelf life of foods. During thermal processing and storage, colour changes from bright green to olive green due to the conversion of chlorophyll (Chl) to pheophytin and pyropheophytin. Factors such as pH, temperature, presence of salts, enzymes and surface-active ions influence the stability of Chl (Choi *et al*. 2002; Nisha *et al.* 2004; Chutintrasri and Noomhorm 2007). However, the stabilizing effect of the common salt is not well established and no information is available on its effect on fluted pumpkin leaves, especially in term of visual colour.

Thermal degradation of food colours has been studied for red cabbage (Dyrby *et al.* 2001), raspberry (Ochoa *et al.* 1999) and pomegranate (Martí *et al.* 2001). Other quality degradation reactions in vegetables during processing and storage are non-enzymatic browning and ascorbic acid loss (Ahmed *et al.* 2002a; Burdurlu and Karadeniz 2003). The need therefore arose to reduce quality degradation in fluted pumpkin by addition of 'natural' pre-treatments. Degradation kinetic parameters like reaction order, rate constant and activation energy provide useful information on the quality changes that occur during thermal processing and storage.

Earlier research relied on the use of spectrophotometric and colorimetric techniques. It is however believed now that colour vision is a complex phenomenon and its measurement is more complex than the absorption by the stimuli at specific wavelengths (Govindarajan *et al.* 1998). The colour observed by human beings is the perception of the wavelengths coming from the surface of the object on the retina of the eyes (Tijskens *et al.* 2001); when light strikes an object, it is reflected, absorbed or transmitted, but it is the reflected light which determines the colour of a material. Therefore, the appearance can change depending on the amount of light, the light source, the observer's angle of view, size and background differences (Giese 2000). Thus the use of colour perception in sensory methodology is often lacking in specificity, sensitivity and reproducibility. Also sensory panels may not be available for routine large scale post harvest and processing quality. Instrumental methods that adequately correlate with sensory methods would help solve these problems. Tristimulus colorimeters have been widely accepted as a rapid and simple instrumental method for measuring visual perception of food products (Ozkan *et al.* 2002). The colour of any food product can be represented in terms of *L*, *a* and *b* values or a combination of these three depending upon the nature of the pigment present.

Therefore, the objective of this study was to determine the kinetics of thermal degradation of visual green colour of fluted pumpkin puree, over a range of thermal processing temperatures of 50–100°C.

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MATERIALS AND METHODS

Fluted pumpkin leaves used for this study were harvested from teaching and research farm in University of Ibadan, Nigeria. The method of Nisha *et al.* (2003) was used for puree preparation. The leaves were sorted and rinsed with tap water. The cleaned leaves were trimmed and pureed with water in the ratio of 1:1 using warring blender. The puree was portioned and common salt (NaCl) was added to get puree containing 1 and 2% by weight of sodium chloride. The heat treatments were carried out at different temperatures (50, 60, 70, 80, 90 and 100°C) for 0-30 min using the method of Wang and Xu (2007). The temperatures were measured with ± 0.1°C accuracy and come-up time was less than 1 minute. Fifty grams each of the pureed fluted pumpkin sample with 0, 1 and 2% salts by weight were taken in a 100 ml beaker and heated at pre-determined temperature/time with frequent stirring. The visual colour was evaluated using a Hunter lab colorimeter model DP-9000 D25A in term of *L* (lightness), *a* (redness and greenness) and *b* (yellowness and blueness). The results were analysed using Oakdale Engineering Datafit 8.2.

Kinetic data analysis

Previous studies showed that thermal degradation of quality attributes in juice followed a first-order reaction (Choi *et al.* 2002; Ahmed *et al.* 2002a; Garzón and Wrolstad 2002). This kinetic type was expressed by the following equations:

$$\ln\frac{C}{C_o} = -kt \qquad (1)$$

where C_o measured initial Hunter colour value (*L*, *a* and *b*) at time zero; *C* is the measured Hunter colour value (*L*, *a* and *b*) or combination of these at time *t*; *t* resident heating time (s); *k* is the reaction rate constant. The plot of ln [C/C_o] against time (t) would be a straight line and the slope would be equal to k at a constant temperature. Arrhenius model dependence on temperature of quality degradation can be expressed as:

$$k = k_o \exp\left(\frac{-E_a}{RT_{abs}}\right) \qquad (2)$$

where k is the rate constant at temperature T_{abs} (Kelvin), k_o is the pre-exponential factor, E_a is the activation energy (kJ/mol) and *R* is the universal gas constant (8.314 J/mol K). Therefore, if the temperature dependence follows Arrhenius' relationship, the plot of ln *k* vs. *1/T* would be a straight line and the slope equal to $-E_a/R$. Hence, activation energy can be evaluated from the expression slope = $-E_a/R$.

Since the major colour of green leafy vegetables puree is green, Hunter *-a* values was considered as the visual parameter to describe the green colour degradation during thermal processing. Therefore equation (1) can be written as:

$$\ln = \left(\frac{-a}{-a_o}\right) = -kt \qquad (3)$$

where *-a*, Hunter *-a* value at time *t*; $-a_o$, Hunter $-a_o$, value at time zero; *k*, rate constant of green colour degradation (s^{-1}).

RESULTS AND DISCUSSION

Effect of salt and temperature on visual green colour of fluted pumpkin puree

Tables 1-3 showed the effect of processing temperature and presence of salt on the Hunter *a* values of fluted pumpkin puree. The initial tristimulus *L*, *a* and *b* values for fluted pumpkin puree were 19.28, -11.32 and 21.83, respectively. There is a consistent decrease in '*a*' values with increase in processing temperature and time. *L* values showed a similar trend, but the decrease in *b* values is insignificant. The change in *L* and *b* values may be due to time and pheophytin-pyripheophytin conversion or due to degradation/ reaction of other components present in the fluted pumpkin puree (Weemaes *et al.* 1999). Further increase in processing temperature led to changes in colour of the fluted pumpkin puree from green to olive green. This is corresponding to a decrease in the *L*-value of the colour scale. This is due to degradation of thermal-labile pigments resulting in the formation of dark compounds that reduced luminosity. This is in agreement with previous studies by (Ávila and Silva 1999; Chuttintrasri and Noomhorm 2007; Kirca *et al.* 2007) in peach and pineapple puree; and black carrot anthocyanins respectively.

The puree also loses its greenness, since the greenness is indicated by *-a*, the study was carried out only with respect to *a* values. During the heat processing at 50°C the puree turned olive green and the *a* value for fluted pumpkin puree changed from an initial value of -11.32 to -10.40, -10.73 and -10.87 in sample with 0, 1 and 2% (w/w) salt addition, respectively after 30 min of heat treatment. The corresponding values after 30 min at 100°C were -3.11, -3.65 and -3.72, respectively. **Tables 1-3** show the effect of treatment concentration on the colour stability of the fluted pumpkin puree, samples treated with 1 and 2% has higher *-a* values. This suggests that salt concentration in puree enhanced stability of colour in the puree. This effect is also visible from the lower rate constant values in puree samples containing 1 and 2% salt as shown in **Table 4**. Chl is reported to be stable at alkaline conditions. The pH of the puree containing 0, 1 and 2% salt (NaCl) was 6.09, 6.15 and 6.24, respectively. Thus, the addition of salt increases the alkalinity of the fluted pumpkin puree slightly, which eventually decrease the rate of degradation of Chl, which is in agreement with the work of Nisha *et al.* (2004).

Degradation kinetics of visual colour of fluted pumpkin puree

Using linear regression, the degradation data were analyzed using Eq. (3) to determine the overall order and rate constant (*k*) for the degradation reaction. Accordingly, ln [$-a/-a_o$] was plotted against time, from which rate constant, *k* was determined. Datafit 8.2 version was used to fit the statistical data. For a reaction following first order kinetics model, the plot of ln [$-a/-a_o$] versus time would be a straight line and the slope would be equal to *k* at a constant temperature. A correlation coefficient > 0.9 in all cases confirmed that the degradation of visual green colour in fluted pumpkin puree indeed follows a first order reaction at all temperatures. **Table 4** shows the rate constant for the visual green colour degradation of fluted pumpkin puree 0, 1 and 2% salt by weight. Samples containing 2% salt gave the lowest rate constants followed by the samples treated with 1% salt and then 0% salt, thus it is evident that green colour or Chl is more stable in green vegetables at 2% salt addition level. This is in agreement with previous studies reported by Nisha *et al.* (2004) who studied the effect of salt in the degradation kinetics of visual green colour in spinach (*Spinacea oleracea* L.). The study revealed that salt concentration had greater effect on colour preservation.

The activation energy for green colour in fluted pumpkin puree with 0, 1 and 2% of salt was calculated to be 68.31 (R^2 = 0.925), 81.75 (R^2 = 0.938) and 81.93 (R^2 = 0.912) $kJmol^{-1}$, respectively (**Fig. 1**). Previous studies have reported wide variation in the activation energies for colour degradation of green vegetable purees. Activation energies of 28.55, 41.15 and 34.01 $kJmol^{-1}$ for spinach puree, mustard leaves and a mixed puree, respectively were reported by Ahmed *et al.* (2002a). Activation energies for colour degradation in green chilli puree (Ahmed *et al.* 2000) and that for heated broccoli juice (Weemas *et al.,* 1999) were reported to be 11.34 – 15.98 and 72.01 $kJmol^{-1}$, respectively. This variation may be attributed to the differences in the raw material and the temperature ranges used in these studies.

Temperature dependence of colour degradation was studied for fluted pumpkin puree and Arrhenius plots (**Fig. 2**); this was used to calculate the activation energy for green colour degradation in fluted pumpkin puree with 0, 1 and 2% of salt.

Calculated activation energies are 68.31 (R^2 = 0.925),

Table 1 Effect of processing temperature and salt concentration on colour degradation of fluted pumpkin puree (10 min processing time).

Treatment	Hunter *Lab*	Temperature (°C)					
		50	60	70	80	90	100
0% NaCl	*L*	19.10	18.74	17.90	17.72	17.75	17.29
	a	-10.98	-10.95	-10.60	-10.51	-8.78	-6.42
	b	21.68	21.60	21.56	21.51	21.39	21.33
1% NaCl	*L*	19.15	18.92	17.96	17.87	17.79	17.69
	a	-11.09	-11.06	-10.72	-9.00	-8.02	-6.64
	b	21.67	21.67	21.63	21.57	21.52	21.47
2% NaCl	*L*	19.20	19.06	18.15	18.00	17.98	17.92
	a	-11.19	-11.19	-10.93	-10.13	-9.32	-6.53
	b	21.77	21.75	21.69	21.63	21.59	21.54

Table 2 Effect of processing temperature and salt concentration on colour degradation of fluted pumpkin puree (20 min processing time).

Treatment	Hunter *Lab*	Temperature (°C)					
		50	60	70	80	90	100
0% NaCl	*L*	18.83	18.00	17.73	17.53	17.13	17.11
	a	-10.69	-10.64	-10.18	-9.58	-6.20	-4.44
	b	21.47	21.46	21.32	21.25	21.19	21.09
1% NaCl	*L*	18.93	18.56	17.88	17.48	17.32	17.19
	a	-10.59	-10.48	-10.40	-9.75	-6.29	-4.70
	b	21.59	21.54	21.44	21.33	21.30	21.20
2% NaCl	*L*	18.95	18.79	17.90	18.77	18.14	17.21
	a	-10.98	-10.89	-10.66	-10.05	-7.10	-4.71
	b	21.68	21.65	21.53	21.47	21.41	21.35

Table 3 Effect of processing temperature and salt concentration on colour degradation of fluted pumpkin puree (30 min processing time).

Treatment	Hunter *Lab*	Temperature (°C)					
		50	60	70	80	90	100
0% NaCl	*L*	18.78	17.73	17.49	17.30	16.84	16.29
	a	-10.40	-10.37	-9.27	-9.91	-5.19	-3.11
	b	21.22	21.18	21.07	21.01	20.86	20.81
1% NaCl	*L*	18.55	17.88	17.75	17.23	17.01	16.84
	a	-10.73	-10.69	-9.98	-11.00	-5.24	-3.65
	b	21.43	21.39	21.24	21.18	21.07	21.00
2% NaCl	*L*	18.77	17.92	17.87	17.65	17.36	16.98
	a	-10.87	-10.84	-10.40	-11.13	-5.89	-3.72
	b	21.58	21.52	21.39	21.34	21.21	21.14

Table 4 Rate constant and correlation coefficient (R^2) for colour degradation of fluted pumpkin puree.

Temperature (°C)	NaCl					
	0%		1%		2%	
	k (s^{-1})	R^2	k (s^{-1})	R^2	k (s^{-1})	R^2
50	2.0E-03±0.177	0.989	1.0E-03±0.0019	0.990	1.0E-03 ±0.187	0.983
60	2.0E-03±0.012	0.993	1.0E-03±0.0014	0.999	1.0E-03±0.0011	0.985
70	4.0E-03±0.187	0.990	3.0E-03±0.0027	0.983	2.0E-03±0.0012	0.991
80	1.8E-03 ±0.018	0.913	1.4E-03±0.0187	0.927	1.3E-03±0.0073	0.912
90	2.6E-03±0.926	0.978	2.3E-03±0.0133	0.968	2.2E-03±0.0092	0.991
100	3.8E-03±0.133	0.995	3.4-03±0.01205	0.979	3.3E-03±0.0012	0.971

81.75 (R^2 = 0.938) and 81.93 (R^2 = 0.912) kJmol^{-1} for fluted pumpkin puree with 0, 1 and 2% of salt. Higher activation energy implies that the rate of colour degradation is less at higher pH. This inferred that rate of colour degradation is lower at higher salt concentration. This is in line with generally perceived notion that the higher the alkalinity the more is the colour stability. These observations are in agreement with the results reported by Ahmed *et al.* (2002b) and Nisha *et al.* (2003).

CONCLUDING REMARKS

The effect of Sodium chloride on the degradation of visual green colour 'a' of fluted pumpkin (*Telfairia occidentalis*) puree was studied over a processing temperature range. The puree lost its colour as the processing temperature and time increased. Studying the degradation kinetic, a first order kinetic was established. The activation energy of the puree increased with increase in treatment concentration. High activation energy in puree treated with 2% NaCl indicates higher stability of Chl even at higher processing temperature.

REFERENCES

Ahmed J, Shivhare US, Raghavan GSV (2000) Rheological characterization and kinetics of colour degradation of green chilli puree. *Journal of Food Engineering* **44**, 239-244

Ahmed J, Kaur A, Shivhare U (2002a) Colour degradation kinetics of spinach, mustard leaves, and mixed puree. *Journal of Food Science* **67**, 1088-1091

Ahmed J, Shivhare US, Sandhu S (2002b) Thermal degradation kinetics of carotenoids and visual color of papaya puree. *Journal of Food Science* **67**, 2692-2695

Ávila IMB, Silva CLM (1999) Modeling kinetics of thermal degradation of colour in peach puree. *Journal of Food Engineering* **39**, 161-166

Burdurlu HS, Karadeniz F (2003) Effect of storage on nonenzymatic browning of apple juice concentrates. *Food Chemistry* **80**, 91-97

Choi MH, Kim GH, Lee HS (2002) Effects of ascorbic acid retention on juice colour and pigment stability in blood orange (*Citrus sinensis*) juice during refrigerated storage. *Food Research International* **35**, 753-759

Chutintrasri B, Noomhorm A (2007) Color degradation kinetics of pineapple puree during thermal processing. *LWT – Food Science and Technology* **40**, 300-306

Dyrby M, Westergaard N, Stapelfeldt H (2001) Light and heat sensitivity of red cabbage extract in soft drink model systems. *Food Chemistry* **72**, 431-437

Garzón GA, Wrolstad RE (2002) Comparison of the stability of pelargonidin-based anthocyanins in strawberry juice and concentrate. *Journal of Food Sci-*

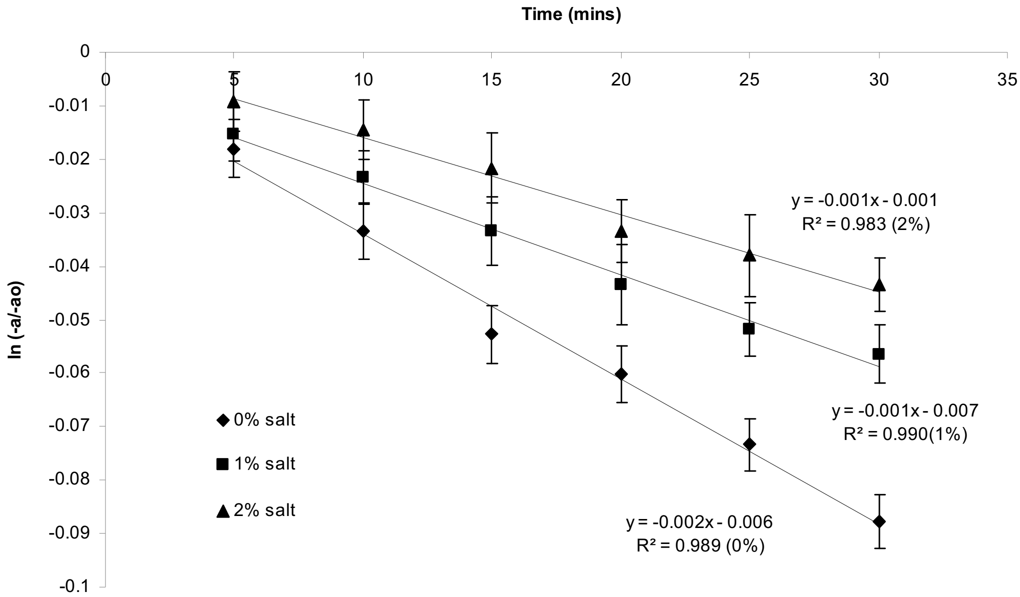

Fig. 1 Plot of ln [-a/-a$_0$] against time (min) at 50°C for fluted pumpkin puree.

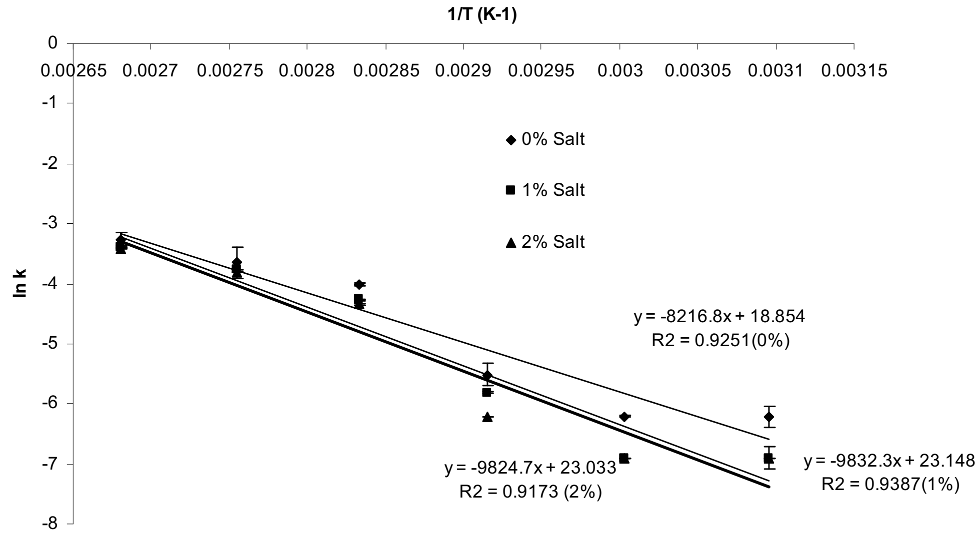

Fig. 2 Arrhenius plot for colour degradation (-a) in fluted pumpkin puree.

ence **67 (5)**, 1288-1299

Giese J (2000) Colour measurement in foods as a quality parameter. *Food Technology* **54 (2)**, 62-65

Govindarajan VS, Rajalakshmi D, Chand N (1998) *Capsicum*: Production, technology, chemistry and quality. Part IV. Evaluation of quality. *CRC Critical Reviews in Food Science and Nutrition* **25**, 185-282

Kírca A, Özkan M, Cemeroğlu B (2007) Effects of temperature, solid content and pH on the stability of black carrot anthocyanins. *Food Chemistry* **101**, 212-218

Martí N, Pérez-Vicente A, García-Viguera C (2001) Influence of storage temperature and ascorbic acid addition on pomegranate juice. *Journal of the Science of Food and Agriculture* **82 (2)**, 217-222

Mosha TC, Gaga HE (1999) Nutritive value and effect of blanching on trypsin and chymotrypsin inhibtor activities of selected leafy. *Plant Food for Human Nutrition* **54**, 271-283

Nisha P, Singhal RS, Pandit AB (2003) A study on the degradation kinetics of visual green colour in spinach (*Spinacea oleacea* L.) and the effect of salt therein. *Journal of Food Engineering* **64**, 135-142

Ochoa MR, Kesseler AG, Vullioud MB, Lozano JE (1999) Physical and chemical characteristics of raspberry pulp: Storage effect on composition and color. *Lebensmittel Wissenschaft und Technologie* **32 (3)**, 149-153

Ozkan M, Yemenicioglu A, Asefi N, Cemeroglu B (2002) Degradation kinetics of anthocyanins from sour cherry, pomegranate, and strawberry juices by hydrogen peroxide. *Journal of Food Science* **6**, 525-529

Wang W, Xu S (2007) Degradation kinetics of anthocyanins in blackberry juice and concentrate. *Journal of Food Engineering* **82**, 271-275

Weemaes CA, Ooms V, Loey AM, Hendrickx ME (1999) Kinetics of chlorophyll degradation and colour loss in heated broccoli juice. *Journal of Agricultural and Food Chemistry* **44**, 2404-2409