KINETICS OF COLOUR CHANGES OF TOMATOES DURING DRYING

A. Unadi[a], R.J. Fuller[b], and R.H. Macmillan[b]

[a]Center for Agricultural Machinery Development, PO Box 2, Serpong 15310, Indonesia
[b]International Technologies Centre, Department of Civil and Environmental Engineering,
The University of Melbourne, Victoria 3052, Australia

ABSTRACT

Colour is one of the parameters determining the quality of dried tomatoes. The changes in colour of the skin of tomatoes during drying in an experimental dryer at various temperatures were measured every two hours by using a Minolta CR 200 colorimeter and the colours were represented in Hunter-*Lab* scale. The objective of this research was to develop a model for predicting colour changes of tomatoes during drying. The decrease in darkness as represented by the δL value varied from 10 to 16%, while the decrease in chroma value (δC) varied from 20 to 37% of the initial values. An empirical logarithmic equation with six constants was derived to fit the data of the chroma changes during drying at various temperatures and times. The model of colour changes of tomatoes can be used for determining the optimum drying temperature to produce acceptable colour of dried tomatoes at reasonable cost.

[*Keywords*: tomatoes; drying; colour]

INTRODUCTION

Drying is one of the methods that can be used to preserve the quality of tomatoes. Dried tomatoes are extensively in the food industry. The quality of dried tomatoes is determined by various parameters such as moisture content, colour, rehydration ratio, pH, flavour, and aroma. Of these, colour is one of the most important parameters and hence it determines consumer preference. Prediction of colour changes during drying process therefore, is very important for determining an appropriate strategy to produce a high quality product.

The effect of temperature and relative humidity on the drying process of fruit and vegetables is relatively well understood, while their effect on colour is not due to lack of information or data describing the process of colour changes. Carotenoid particularly lecopene, is responsible for colour of tomatoes (Shewfelt *et al.*, 1988). However, the changes in colour of tomatoes is not only caused by the deterioration of lecopene. The complex reactions during drying, particularly at high temperature, which lead to browning and discolouration in some fruits as reported by some researchers (Reynold, 1965; Abets and Wrolstand, 1979; Cornwell and Wrolstand, 1981; Lozano and Ibarz, 1996) may also take place in tomatoes. However, these reports are limited to the effect of temperature and time on the operators control for colour. Therefore it is necessary to study the colour changes of tomatoes during drying in which the air temperature and drying time was assumed to be the factors most strongly affecting the final product.

The Hunter colour scale has been used widely to quantify the colour of fruit and vegetables (Thai *et al.*, 1990; Sanguansri *et al.*, 1993; Sanguansri *et al.*, 1995; Lee *et al.*, 1996; Lozano and Ibarz, 1996; Madamba, 1997). The darkness, i.e., white and black is represented by the parameter L, while the colour components, i.e., red, yellow, green, and blue are represented by the parameters $+a$, $+b$, $-a$ and $-b$ respectively, all of which can be combined as chroma by the following relationship:

$$C = (a^2 + b^2)^{0.5} \qquad (1)$$

where $+a$ is red; $+b$ is yellow; $-a$ is green; $-b$ is blue, and C is chroma.

The chroma, C, is believed to be the most significant measure of colour for dried tomatoes. Sanguansri *et al.* (1993) studied the effect of cabinet, heat pump, sun, and solar dryers at temperature of about 50°C on tomato colour and found that the darkness (L) of tomatoes increases between 0-5%, while the chroma decreases between 35-67% of the initial values. Because there were only two points of colour measurement during drying, an algorithm for the colour changes could not be developed.

The objective of this study was to evaluate the colour changes of tomatoes during drying at various temperatures using the Hunter colour scale. This was to be the basis for an algorithm to predict colour

changes which could then be included in a model to simulate the performance of a drier. Thus the effect of various drying strategies on colours could then be included in the overall evaluation of its performance.

MATERIALS AND METHODS

Fully mature tomatoes of Acardia variety were used in the experiment. The fruits were harvested 65 days after transplanting, and stored in a cool storage at temperature of 5°C for 1-5 days. Tomato fruit samples were cut in halves and spread cut side uppermost on three stainless steel mesh trays as replication and this has been more fully described elsewhere by Unadi *et al.* (1998). The samples were then dried in the chamber from a moisture content of about 15 kg water kg^{-1} dry matter (dry basis) to about 0.12 kg kg^{-1} (dry basis). The drying experiments were conducted at 40°, 50°, 60°, 70°, and 80°C and at a relative humidity of approximately 15%.

The temperature and relative humidity in the drying chamber were monitored by thermocouples calibrated with a "HAAKA" constant temperature bath using a British Standard thermometer with an accuracy of 0.1°C. A Data-Taker DT50 and a PC Toshiba 1200 computer were programmed to record the dry and wet bulb temperatures in the drying chamber every hour. Recordings were stopped after the moisture content of tomatoes reached about 11% (dry basis), i.e., after about 27 hours and 63 hours at drying temperatures of 80° and 40°C, respectively.

The colour of tomatoes defined in terms of Hunter *L*, *a*, and *b* parameters was measured with a Minolta CR-200 colorimeter calibrated with standard white reflector plate ($L = 97.87$, $a = -0.48$ and $b = 1.91$) (Anon, 1994). The *L*, *a*, and *b* represent darkness (white and black), red and green, and yellow and blue, respectively. There were large colour variations in the halved tomatoes, particularly at the cut surface because the initial colour of pulp, seeds, and core was different, and therefore colour measurements of the skin were taken. The measurements were made at three different positions on each of nine pieces making a total of 27 colour readings taken every 3 hours.

The moisture content of the tomato samples during drying was measured by weighing the trays after each colour measurement corrected with the weight of empty trays. The final moisture content of tomatoes was determined by drying the samples at 70°C following the standard oven method used for fruit and vegetables (AOAC, 1980).

The data from each drying temperature were plotted and the line trend was developed using Microsoft Excel program to generate equations that relate the colour changes and the drying time. To generalise these equations, the constants of each logarithmic equation were fitted to an equation using the same method to relate the effect on temperature and colour.

RESULTS AND DISCUSSION

The initial colour of the fresh tomato samples varied, as shown by the value of colour parameters *L* and *C* (Table 1). Consequently, the colour of dried tomatoes also varied. Since an analysis of colour change on absolute value of colour was difficult, it was then based on the differences in darkness (δL) and chroma (δC) between initial colour value (L_i and C_i) and those at specified drying time t (L_t and C_t), where $\delta C = C_i - C_t$ and $\delta L = L_i - L_t$ (or C_f and L_f for final colour).

The decrease in darkness value (δL) varied from 10.4% to 16.2 % while the decrease in chroma value (δC) varied from 19.9% to 26.5 % (Table 1). The data show that the decrease in chroma is much higher than that in darkness, and therefore analysing the chroma change is more likely to produce a meaningful

Table 1. The colour changes of tomatoes before and after drying (average of 27 readings).

T	Initial colour							Final colour							Colour difference			
(°C)	L_i	CV (%)	a_i	CV (%)	b_i	CV (%)	C_i	L_f	CV (%)	a_f	CV (%)	b_f	CV (%)	C_f	δL	(%)	δC	(%)
40	38.04	4.31	22.44	5.29	17.10	3.31	28.22	34.45	2.92	15.50	1.93	13.70	3.63	20.67	3.59	12.72	7.55	19.85
50	38.11	3.69	21.90	2.85	18.53	5.73	28.69	33.45	3.96	14.44	3.92	14.14	5.85	20.22	4.66	16.24	8.47	22.23
60	40.12	5.05	24.40	6.31	23.25	33.70	4.92	34.72	2.82	15.23	2.92	18.24	2.82	24.15	5.40	16.02	9.55	23.80
70	38.04	2.95	24.20	5.47	24.50	34.47	4.22	34.47	3.52	14.49	19.62	3.96	24.39	3.52	3.57	10.36	10.08	26.50
80	41.23	3.92	22.38	3.92	25.10	33.63	5.47	37.20	3.15	11.80	19.40	3.82	22.73	2.66	4.03	11.98	10.90	26.44

L = darkness (white and black); *a* = red and green; *b* = yellow and blue; *C* = chroma
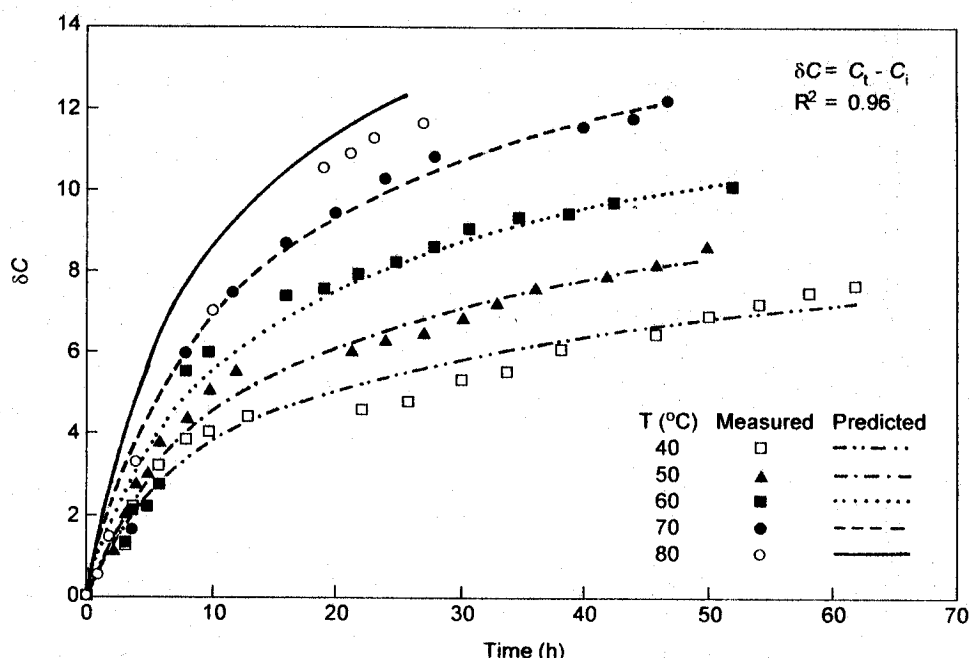
Fig. 1. The predicted change of chroma (δC) of tomatoes during drying at various temperatures.

relationship between drying condition and final colour.

The plot of δC versus time of each treatment presented in Fig. 1 shows that δC increases as the drying temperature and time increase. For the first eight hours, little differences in the effect of temperature could be detected, but since this represents at most 20% of the drying time it is not considered to be significant. However, after eight hours, the value of δC was higher at a higher drying temperature and a longer drying time.

The equation for the data in Fig. 1 was generated and a logarithmic equation was found to be the most appropriate for fitting the data, indicated by the high value of coefficient of determination (R^2), i.e., between 0.90-0.98. The general logarithmic equation used is as follow:

$$\delta C = F \log (G\, t) \qquad (2)$$

where F and G are constants.

The constants F and G are represented in Table 2 and they vary with the drying time.

To generalise the equation, the constants F and G from each curve were plotted against the drying temperature again, and an equation for each curve was generated. A quadratic equation was found to be the most appropriate to describe this relationship. The general equations to relate the constants F and G to the drying temperature are:

$$F = m\, T^2 + n\, T + p \quad \text{and} \qquad (3)$$
$$G = q\, T^2 + r\, T + s \qquad (4)$$

The empirical logarithmic equation therefore became:

$$\delta C = (mT^2 + n\, T + p) \log ((qT^2 + rT + s)\, t) \qquad (5)$$

where: m, n, p, q, r, and s are constant

        T is temperature (°C)

        t is time (hour)

        δC is decrease in chroma

The values of constants m, n, p, q, r, and s are given in Table 3.

The logarithmic equation (5), with temperature dependent constants F and G, is sufficient for predicting the changes of chroma (δC) of tomatoes during drying, indicated by high value coefficient of determination (R^2) of 0.96. The predicted values of δC are represented in Fig. 1.

Table 2. The value of constants F and G of equation 2 at various temperatures.

Temperature (°C)	Constant values	
	F	G
40	-4.18	0.791
50	-4.78	0.979
60	-6.46	0.703
70	-10.94	0.380
80	-9.50	0.757

Table 3. Constants for the equations 2, 3, and 5.

Constants	Value
m	-9.55×10^{-4}
n	-1.83×10^{-2}
p	-1.92
q	1.77×10^{-4}
r	-2.21×10^{-2}
s	1.39

CONCLUSION

Drying temperature has a significant effect on the changes of chroma (δC) of tomatoes. The change of colour of tomatoes during drying is not only caused by deterioration of lecopene but it is a complex process that needs to be fully understood. Increasing the drying temperature reduces the colour parameter chroma of tomatoes significantly. The model for predicting the colour of tomatoes during drying can be used in developing an optimum drying strategy to improve the quality of dried tomatoes.

REFERENCES

Anon. 1994. Instruction manual for chroma meter CR 200, Minolta.

AOAC. 1980. Official method of analysis. 13th ed. Association of Official Analytical Chemistry, Washington, DC.

Abets, J.E. and R.E. Wrolstand. 1979. Causative factors of colour deterioration in strawberry preserves during processing and storage. J. Food Sci. 44: 75-78.

Cornwell, C.J. and R.E. Wrolstand. 1981. Clarified natural apple juice: production and storage. J. Food Sci. 46: 515-518.

Lee, G.H., J.M. Bunn, Y.J. Han, and D.R. Decoteau. 1996. Determination of optimum levels of light irradiation needed to control ripening of tomato. Trans. ASAE 39(1): 169-175.

Lozano, J.E. and A. Ibarz. 1996. Colour changes of concentrated fruit pulp during heating at high temperatures. J. Food Engin. 4: 305-373.

Madamba, P.S. 1997. Optimisation of the drying process: An application to the drying of garlic. Drying Technol. 15 (1): 117-136.

Reynold, T.H. 1965. Chemistry of non-enzymatic browning II. Adv. Food Res. 14: 167-210.

Sanguansri, L., M. Foster, P. Drew, N. Guirguis, and I. Gould. 1993. Feasibility studies on processing tomato waste and dried tomato product. Report for The Australian Processing Tomato Research Council and The Horticultural Research and Development. Australian Food Industry Science Centre, Werrebee, Victoria, Australia.

Sanguansri, L., M. Foster, and P. Drew. 1995. Improved quality for dried tomatoes: A final report for The Australian Processing Tomato Research Council and The Horticultural Research and Development, No. TM-304. Australian Food Industry Science Centre, Werrebee, Victoria, Australia.

Shewfelt, R.L., C.N. Thai, and J.W. Davis. 1988. Prediction of changes in colour of tomatoes during ripening at different constant temperature. J. Food Sci. 53(5): 1433-1437.

Thai, C.N., R.L. Shewfelt, and J.C. Garner. 1990. Tomato colour changes under constant and variable storage temperature: Empirical model. Trans. ASAE 33(2): 607-175.

Unadi, A., R.J. Fuller, and R.H. Macmillan. 1998. Predicting equilibrium moisture properties of tomatoes at different temperatures and relative humidities. Food Australia, Official Journal of AIFIST Inc. 50: 200-203.