Rehydration characteristics of dehydrated West African pepper (Piper guineense) leaves

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Abstract

The rehydration characteristics of dehydrated West African pepper leaves were investigated at hydration temperatures of 28, 60, 70, and 80°C. Four treatments were given to the leaves: blanched and sun dried, unblanched and sun dried, blanched and shade dried, and unblanched and shade dried. The hydration process of the dehydrated leaves was adequately described by the Peleg’s equation. As the hydration temperature increased from 28 to 70°C, there was a significant decrease in the Peleg’s constant $K_1$, while for most of the leaves the Peleg’s constant $K_2$ varied with temperature. Rehydration ratio values ranged from 3.75 in blanched shade dried leaves to 4.26 in unblanched sun dried leaves with the unblanched leaves generally exhibiting higher ratios than the blanched leaves.

Introduction

West African pepper also known as Guinea pepper or Ashanti pepper is a herbaceous climber belonging to the Piperaceae family. It is a perennial plant that is characterized by heart-shaped leaves. Its leaves are used as flavoring for stews. Owing to their short shelf life and seasonal nature, the leaves are often dried to preserve them. Such leaves, however, must be rehydrated prior to its use. Rehydration is a process which is aimed at restoring the properties of a raw material when the dried material comes in contact with water (An et al. 2013). Rehydration of food materials is often carried out by soaking the dried material in water (Garcia-Pascual et al. 2005). Rehydration may be regarded as a measure of the injury to the material which occurs as a result of drying and treatment that precedes dehydration (McMinn and Magee 1997). The extent of rehydration depends on the degree of structural and cellular disruption (Krokida and Marinos-Kouris 2003). Jayaraman et al. (1990) noticed irreversible cellular rupture and dislocation, which led to the loss of integrity and consequently, a dense structure of collapsed, greatly shrunken capillaries with reduced hydrophilic properties, as seen by the inability to imbibe enough water to fully rehydrate. The rehydration characteristics of dried food materials are used as a quality parameter and show whether physical and chemical changes occurred during the drying process due to process conditions, pretreatments and sample composition (Lewicki 1998). Physical and chemical changes that occur during drying affect the quality of the dried material such that even with the addition of water, the properties of the raw material cannot be restored (Krokida and Marolis 2001).

Studying the rehydration characteristics of food materials is, therefore, important, as this information is necessary to optimize processes from a quality viewpoint since rehydration is a key quality aspect for those dried products that have to be reconstituted before their consumption (Garcia-Pascual et al. 2006). In an attempt to simplify the mode of water absorption by food materials, a nonexponential empirical formula was proposed and became known as the Peleg’s equation (Peleg 1998).

Peleg’s equation can be written thus:
Weight of the rehydrated material

withdrawn from the water bath after 15, 30, 45 min, 1 h, in a thermostatically controlled water bath. Beakers were
° rehydration temperatures were used: 28, 60, 70, and 80
immersion in 250 mL beakers filled with water. Four
for each experiment. The leaves were rehydrated by
100
mined by drying 5 g of the dried leaves in an air oven at

°

rehydration of the reconstituted leaves were

African pepper leaves dried under different conditions.

Materials and Methods

Freshly harvested West African pepper leaves were
washed, destalked, and sliced using a sharp kitchen knife
to sizes ranging between 15 and 20 mm. The leaves were
divided into four portions: two portions were blanched in
water at 100°C for 10 sec while the other two portions
were not blanched. A portion each from the blanched
and unblanched samples were sun dried while the other
two portions were not blanched. A portion each from the blanched
and unblanched leaves in the tempera-
ture range of 60 and 100°C.

The objective of this study was to examine whether
Peleg’s equation can be used in modeling the water
absorption behavior of blanched and unblanched West
African pepper leaves dried under different conditions.

Results and Discussion

The rehydration curves of the blanched and unblanched
leaves dried under the sun and shade are shown in Fig-
ure 1A–D. It was observed that the initial rate of water
uptake increased as the temperature increased. This sug-
gests that rapid rehydration can be achieved when the
temperature of the water is high. Figure 1A–D shows that
a prolonged soaking time does not contribute to further
water uptake. Maharaj and Sankat (2000) made a similar
observation during the rehydration of dehydrated dasheen
leaves. At all the temperatures used in the study, it was
observed that the unblanched sun dried leaves had the
highest uptake of water. A summary of the linear regres-
sion models fitted to the data at the different hydration
temperatures is shown in Table 1. The coefficients of
determination were found to be high in all cases
(R² > 0.97) indicating a good fit of the experimental data
to Peleg’s model at all the examined temperatures.

Peleg’s constant K₂

Values obtained for the Peleg’s constant K₂ are presented
in Table 1. Peleg’s constant K₂ is related to maximum
water absorption capacity, that is, the lower the K₂, the
higher the water absorption capacity (Turhan et al.
2002). Abu-Ghannam and McKenna (1997) reported that
K₂ is a constant that defines the equilibrium moisture
content. In this study, the relationship between tempera-
ture and K₂ was insignificant (P > 0.05) and the values of
K₂ were not always constant with temperature. The
blanched sun dried, unblanched sun dried, and blanched
shade dried leaves had highest K₂ values at 28°C. This

\[
M_t = M_o + t/(K_1 + K_2 t) \quad (1)
\]

As \( t \to \infty \)

\[
M_e = M_o + 1/K_2 \quad (2)
\]

Linearizing equation (1) will give:

\[
t/(M_t - M_o) = K_1 + K_2 t \quad (3)
\]

where \( M_t \) is moisture content at time \( t \) (% db), \( M_o \) is ini-
tial moisture content (% db), \( t \) is rehydration time (min), \( K_1 \) is the Peleg’s rate constant (min/%mc db), \( K_2 \) is the
Peleg’s capacity constant (%mc db)⁻¹, and \( M_e \) is the equilib-
rium moisture content (% db). For the equation
fitting, the curvilinear portion of the hydration data is
often employed. This is because the Peleg’s equation is
applicable to the curvilinear segment of the sorption
curve (Maharaj and Sankat 2000).

The applicability of Peleg’s equation has been demon-
strated for some leafy vegetables. Maharaj and Sankat
(2000) reported that Peleg’s equation could adeqately
describe the water absorption characteristics of both
blanched and unblanched dasheen leaves in the tempera-
ture range of 60 and 100°C.

The rehydration abilities of the reconstituted leaves were
also investigated.

Rehydration ratio = Weight of the rehydrated material
Weight of the dehydrated material

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means that the maximum water absorption capacity of these leaves was lowest at 28°C. However, for the unblanched shade dried leaves, the Peleg’s constant $K_2$ was fairly constant at all the temperatures. Sopade et al. (1994) reported that $K_2$ values for some cowpea varieties were constant with soaking temperature; while for dashen leaves, it was observed that $K_2$ changed with temperature for steam blanched and alkali blanched leaves (Maharaj and Sankat 2000).

Peleg’s $K_2$ values were used to calculate the equilibrium moisture content of the leaves according to equation (2) (Table 2). It was observed that at almost all the temperatures, the sun dried leaves had higher values than their shade dried counterparts regardless of whether they were blanched or not. Equilibrium moisture content of all the hydrated leaves was lower than those reported for dashen leaves (Maharaj and Sankat 2000). There was a close agreement in the equilibrium moisture content values for blanched sun dried, unblanched sun dried, blanched shade dried, and unblanched shade dried leaves determined by experimental and Peleg’s equation at hydration temperatures of 28, 60, 70, and 80°C.

**Peleg’s rate constant $K_1$**

The Peleg’s constant $K_1$ decreased significantly as the hydration temperature increased from 28 to 70°C (Table 3). This suggests a corresponding increase in the initial water absorption rate (Turhan et al. 2002). The reciprocal of $K_1$ is equivalent to the initial rate of hydration (Maharaj and Sankat 2000). It was observed that the values of $1/K_1$ were significantly ($P < 0.05$) higher at 70 than at 80°C for the blanched and unblanched shade dried leaves while values for the blanched and unblanched sundried leaves were not significantly ($P > 0.05$) different at 70 and 80°C. The lower values of $1/K_1$ at 80°C may probably be due to the fact that the high soaking water temperature resulted in shrinkage and/or loss of elastic properties of cell tissues rather than causing an opening up of pores, which invariably reduced the rate of initial hydration (Tunde-Akintunde 2008).

Various researchers have shown that $K_1$ is a temperature-dependent constant (Sopade et al. 1994; Maharaj and Sankat 2000). In this study, for most of the leaves, a significant linear relationship ($R^2$ ranged between 0.91 and

**Figure 1.** Water absorption characteristics of blanched and unblanched West African pepper leaves dried under different conditions at different temperatures. bsh = blanched and shade dried; ubsh = unblanched and shade dried; bsn = blanched and sun dried; ubsn = unblanched and sun dried.
Table 1. Summary of linear regression models fitted to (M_t – M_∞) versus t for West African pepper leaves hydrated at 28–80°C.

| Treatment          | Temperature (°C) | Estimated slope K_2 (% mc db)^{-1} | P     | R^2   |
|--------------------|------------------|-----------------------------------|-------|-------|
| Blanched           | 28               | 4.17 x 10^{-3}                    | 0.000 | 0.982 |
| sun dried          | 60               | 3.00 x 10^{-3}                    | 0.000 | 0.985 |
|                    | 70               | 3.33 x 10^{-3}                    | 0.000 | 0.994 |
|                    | 80               | 3.1 x 10^{-3}                     | 0.000 | 0.997 |
| Unblanched         | 28               | 4.09 x 10^{-3}                    | 0.000 | 0.988 |
| sun dried          | 60               | 2.70 x 10^{-3}                    | 0.000 | 0.978 |
|                    | 70               | 3.40 x 10^{-3}                    | 0.000 | 0.973 |
|                    | 80               | 2.20 x 10^{-3}                    | 0.000 | 0.985 |
| Blanched           | 28               | 4.47 x 10^{-3}                    | 0.000 | 0.993 |
| shade dried        | 60               | 4.20 x 10^{-3}                    | 0.000 | 0.996 |
|                    | 70               | 3.97 x 10^{-3}                    | 0.000 | 0.998 |
|                    | 80               | 3.49 x 10^{-3}                    | 0.000 | 0.997 |
| Unblanched         | 28               | 3.81 x 10^{-3}                    | 0.000 | 0.986 |
| shade dried        | 60               | 3.89 x 10^{-3}                    | 0.000 | 0.987 |
|                    | 70               | 3.99 x 10^{-3}                    | 0.000 | 0.992 |
|                    | 80               | 3.97 x 10^{-3}                    | 0.000 | 0.997 |

Table 2. Equilibrium moisture content of hydrated West African pepper leaves determined experimentally and by predictive methods.

| Treatment          | Temperature (°C) | Observed equilibrium moisture content (% db) | Predicted equilibrium moisture content (% db) |
|--------------------|------------------|---------------------------------------------|---------------------------------------------|
| Blanched           | 28               | 233                                         | 252                                         |
| sun dried          | 60               | 340                                         | 348                                         |
|                    | 70               | 300                                         | 313                                         |
|                    | 80               | 305                                         | 315                                         |
| Unblanched         | 28               | 250                                         | 260                                         |
| sun dried          | 60               | 320                                         | 385                                         |
|                    | 70               | 285                                         | 309                                         |
|                    | 80               | 465                                         | 467                                         |
| Blanched           | 28               | 235                                         | 234                                         |
| shade dried        | 60               | 250                                         | 253                                         |
|                    | 70               | 263                                         | 267                                         |
|                    | 80               | 275                                         | 302                                         |
| Unblanched         | 28               | 245                                         | 278                                         |
| shade dried        | 60               | 250                                         | 273                                         |
|                    | 70               | 257                                         | 266                                         |
|                    | 80               | 260                                         | 267                                         |

0.96; P < 0.05) was found to exist between temperature and K_1 which agrees with the findings of previous studies. However, for the unblanched shade dried leaves, K_1 was not found to be temperature dependent (R^2 = 0.88; P = 0.06). Abu-Ghannam and McKenna (1997) observed that K_1 for unblanched beans was not temperature dependent as this was reflected in a low correlation coefficient (R^2 = 0.61). This suggests that K_1 could also be dependent on other properties of the food materials in question. Initial hydration rates as determined by 1/K_1 were highest for blanched sun dried leaves at all the temperatures studied. The blanched shade dried leaves also exhibited higher initial hydration rates than the unblanched shade dried leaves. This may suggest that blanching can improve initial hydration rates, and therefore the rehydration characteristics of West African pepper leaves.

Rehydration ratio

Rehydration is one way to analyze dried products. A high value of rehydration ratio means the dried product has a good quality because the pores allow water to reenter the cells (Noomhorm 2007). Rehydration ratio ranged from 3.75 in blanched shade dried leaves to 4.26 in unblanched sun dried leaves (Table 4). Generally, it was observed that the unblanched leaves had higher ratios than the blanched leaves. Rajeswari et al. (2011) observed a similar trend with amaranthus leaves. It was also observed that sun drying led to higher rehydration ratios than shade drying.

Table 3. Peleg’s K_1 values for West African pepper leaves hydrated at 28–80°C.

| Treatment                  | Temperature (°C) | K_1          | 1/K_1         |
|---------------------------|------------------|--------------|---------------|
| Blanched sun dried        | 28               | 4.21 x 10^{-2} | 24            |
|                           | 60               | 1.45 x 10^{-2} | 69            |
|                           | 70               | 6.00 x 10^{-3} | 167           |
|                           | 80               | 7.00 x 10^{-3} | 143           |
| Unblanched sun dried      | 28               | 4.53 x 10^{-2} | 22            |
|                           | 60               | 2.01 x 10^{-2} | 50            |
|                           | 70               | 1.2 x 10^{-2}  | 83            |
|                           | 80               | 1.2 x 10^{-2}  | 83            |
| Blanched shade dried      | 28               | 5.73 x 10^{-2} | 17            |
|                           | 60               | 1.70 x 10^{-2} | 59            |
|                           | 70               | 6.1 x 10^{-3}  | 164           |
|                           | 80               | 1.06 x 10^{-2} | 94            |
| Unblanched shade dried    | 28               | 8.07 x 10^{-2} | 12            |
|                           | 60               | 1.96 x 10^{-2} | 51            |
|                           | 70               | 8.70 x 10^{-3} | 115           |
|                           | 80               | 1.60 x 10^{-2} | 63            |

Table 4. Rehydration ratio of hydrated West African pepper leaves.

| Treatment                  | Rehydration ratio |
|---------------------------|-------------------|
| Blanched sun dried        | 3.77              |
| Unblanched sun dried      | 4.26              |
| Blanched shade dried      | 3.75              |
| Unblanched shade dried    | 3.83              |

Values are means of duplicate determinations.
Conclusion
The Peleg’s model could adequately describe the water absorption of blanched sun dried, unblanched sun dried, blanched shade dried, and unblanched shade dried leaves between 28 and 80°C. The model could also predict the equilibrium moisture content of the leaves. The Peleg’s constant $K_1$ decreased significantly as the hydration temperature increased from 28 to 70°C. The Peleg’s constant $K_2$ was not constant with temperature for most of the leaves. Only the unblanched shade dried leaves, exhibited fairly constant values at all the temperatures.

Conflict of Interest
None declared.

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