International Journal of Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2025.5.3

Volume 11, Issue 5
May - 2025

A contradiction-based Approach for Air Temperature Choice in Thin-layer Drying of Cassava Roots

P. Doua[1] and L. Bitjoka[2]

[1]Laboratory of Reactions, Extraction and Drying, National School of Agro-Industrial Sciences, University of Ngaoundéré, Po. Box. 454 Ngaoundéré – Cameroon

[2]Laboratory of Energy, Signal, Imaging and Automation, National School of Agro-Industrial Sciences, University of Ngaoundéré, Po. Box. 454 Ngaoundéré – Cameroon

---

ABSTRACT

Setting the drying temperature of cassava slices remains up to now a matter of personal decision from authors, varying from an author to another and for the same author, varying from an experiment to another one. The primary aim of this manuscript is to introduce a decision-making instrument for determining the optimal temperature setting during the thin-layer drying process of cassava slices in general, the thin-layer drying process of bitter cassava roots slices in particular. The thermal conditions for drying should be higher than 37 °C to permit the hydrolysis of cyanogenic compounds into hydrogen cyanide (HCN) and it should not be higher than 30 °C to favor the elimination of HCN upon that of water and prevent the denaturation of thermosensitive nutrients in cassava slices. The TRIZ separation in time method provided a set of three steps for solving that problem. First step, in a preliminary action, cassava slices were introduced in water set at 37 °C for 6 h. The HCN was produced and a large quantity eliminated by solubilization. Second step, during that period, a cassava moisture prior compensation was also achieved: cassava slices uptook additional water, favoring the elimination of the residual HCN at a unique drying temperature, without any particular care. Third and last step, cassava slices were then dried at 35 °C, 40 °C and 45 °C, values of the residual HCN content were 7.23 ± 1.30 mg HCN/kg, 6.42 ± 2.4 mg HCN/kg and 8.06 ± 1.1 mg HCN/kg, respectively. All those values are less than 10 mg HCN/kg, the maximum admissible value for human consumption, set by the World Health Organization.

Keywords: Temperature, Cassava cyanide, Physical contradiction, Thin-layer drying, TRIZ.

---

1. INTRODUCTION

Cassava (*Manihot esculenta, Crantz*) serves as a primary staple food source for over one billion individuals globally [1,2]. The nutritional profile of 160 g of fresh cassava includes: 306 calories, 2.27 g of protein, 63.4 g of carbohydrate, 3.04 g of fiber, 27.2 mg of Ca, 35.2 mg of Mg, 451 mg of K, 29.1 mg of vitamin C, 0.077 mg of riboflavin and 1.35 mg of niacin [3,4].The freshly harvested cassava roots initiate microbial and physiological degradation almost instantaneously post-harvest and possess a limited shelf life of merely three days [3,5].

The aim of thin-layer drying of cassava is to preserve its physico-chemical properties for a long period, in order to ensure food security for humans. Thin-layer drying of cassava is a 3-step process: firstly, hot and dehumidified air is brought in contact with the product; secondly, the liquid moisture on the product surface is vaporized and finally, humid air is moved away. Heating cassava samples for liquid moisture vaporization goes along with many contradicting requirements, as far as temperature is concerned. The influence of the drying temperature on cassava samples can be described in several ways. High values of drying temperature can cause case hardening of cassava, that is a situation responsible for the hardening of the outside layer of cassava. The moisture can therefore be trapped on the inside of the cassava which could eventually lead to mold and spoiled food [3,6]. Another consequence of elevated drying temperatures is the occurrence of non-enzymatic browning, which constitutes a chemical reaction responsible for imparting a brown hue to food substances in the absence of enzymatic activity [7]. As the ambient temperature increases, a greater quantity of starch or carbohydrates is likely to undergo hydrolysis into sugars; furthermore, upon thermal processing of these carbohydrates, the resultant sugars undergo Maillard reaction, resulting in browning, which serves as an indicator of inferior product quality [8,9]. Higher drying temperatures cause the denaturation of thermosensitive nutrients in cassava. According to reference [10], water-soluble nutrients like Vitamin C, riboflavin and niacin are thermo-sensitive, and vitamin C begin to denature at temperatures as low as 30 °C, along with exposure to air oxidation for more than 12 hours. Cassava roots contain cyanogenic glycosides that are responsible for its toxicity [11].

Cyanogenic glycosides undergo hydrolysis by the endogenous cell wall enzyme linamarase, resulting in the formation of acetone cyanohydrin, which subsequently decomposes into hydrogen cyanide (HCN) at temperatures exceeding 37°C, as noted by reference [12]. The augmentation of linamarin degradation into volatile byproducts via linamarase may mitigate the toxicity associated with cassava consumption. The enzymatic activity of linamarase is rapidly diminished at temperatures surpassing 75 °C [13,14]. Moreover, the perilous temperature range for edibles is identified as lying between 8 °C and 60 °C, highlighting the environmental factors where food is especially prone to the increase of disease-causing bacteria, potentially causing health issues when eaten [14,15]. Fresh cassava root is classified as a high-risk food due to its moisture content, elevated levels of starch or protein, and neutral acidity [13,15]. Thin-layer drying actors are therefore confronted to the following contradiction: the drying temperature should be high to end the drying operation rapidly, and it should be low to prevent the premature elimination of water upon that of HCN and the destruction of thermo-sensitive nutrients. Regardless of the broad spectrum of existing literature, the selection of a specific value for the drying air temperature displays considerable variation among various authors; additionally, even within an individual author's body of work, the values assigned to drying air temperature can differ notably from one experimental study to another, lacking any definitive or objective standards [1,16,17,18].

The objective of this paper is to work out a decision-making tool that can help users to fix the value of the air temperature in thin-layer drying of cassava roots.

2. MATERIALS AND METHODS

2.1. Materials

A newly harvested cassava tuber was procured at the municipal marketplace of Ngaoundéré (7°19' N and 13°33'E) (Cameroon). A universal oven U, model size 750, from the MEMMERT Heating and Drying Ovens Company was used as dryer. Temperature measurement ranges from 0 °C to 95 °C with a precision of ± 0.2. A 2-digit precision balance, HEMA Elektronish AAM, was used to measure the mass of the samples in the range of 0.00 to 2000.00 g. The precision of measurement of that balance is ± 0.1. A manual stainless-steel dicer of the Genius Nicer-Dicer Plus TM was used to cut the cassava root in elements of 1 mm thick. A digital vernier caliper was used to measure the thickness of cassava slicers, its measuring range varies from 0 to 200 mm with a precision of ± 0.05 mm. A Chrono-Thermo-Hygrometer-speedometer HAISHI Quartz KD 3610 was employed to quantitatively assess the drying duration, ambient air temperature, relative humidity of the air, and air velocity in a systematic manner. The measurement of the relative humidity was done with a precision of ± 2 %. Measurement of the air velocity was done with a precision of ± 0.05.

2.2. Methods

2.2.1. Composition of a TRIZ technical system

TRIZ represents the Russian acronym for Teorija Reshenija Izobretateliskih Zadatch, which is rendered in English as the Theory of Inventive Problem Solving (TIPS). Developed by Genrich Altshuller, a distinguished engineer and inventor from the former USSR, TRIZ serves as a comprehensive toolkit for engineering problem resolution, spanning the years 1946 to 1998. This methodology effectively consolidates historical solutions and achievements to illustrate a systematic approach for addressing prospective challenges. TRIZ defines a technical system as a set of three elements E_1, E_2, E_3. E_1 is called 'tool' or 'active' object. E_2 is called 'product' or 'passive' object and E_3 is called 'facilitator' or 'witness'. In a technical system, E_1 interacts with E_2 in order to change its

DOI: 10.31695/IJASRE.2025.5.3

physical state or its chemical composition or its shape. The interaction between E_1 and E_2 is called 'Useful function'. In some cases, the interaction takes place between E_1 and E_2 without E_3, the technical system is called a 'Vepole', but if E_1, E_2 and E_3 and present, the technical system is called 'TRIAD' [19,20].

2.2.2. Formulation of a physical contradiction

A physical contradiction arises within a technical system when: "an element E1, E2, or E3 is required to possess characteristic 'A' to execute a beneficial function AND simultaneously, this same element must exhibit characteristic 'non-A' to comply with prevailing constraints and specifications." The ideal final result consists to have characteristic "A" where and when necessary and characteristic "non-A", where and when necessary [19,21].

2.2.3. Solving a physical contradiction

There are 4 separation methods for solving physical contradictions:

- Separation in Space: one solution in one place, the opposite solution at another.
- Separation in Time: one solution at one time, the opposite solution at another.
- Separation on Condition: opposite solution at the same time at the same place; one solution for one element, the opposite for another.
- Separation in System levels: separate by scale (switch to sub-system or switch to super-system) or switch to inverse system or switch to another system.

The full description of those separation methods is given by reference [19].

2.2.4. Assessment of the moisture content in cassava

In order to determine both the initial and final moisture content in cassava, three samples were positioned in an oven programmed to a temperature of 105 °C for 24 hours. The masses of the samples were recorded prior to their insertion into the oven and subsequently 24 hours later. The calculation of the initial moisture content of the cassava samples, expressed on a dry basis, was performed utilizing equation (1);

$$X_{i\_db} = \frac{M_i - M_d}{M_d} \qquad (1)$$

Where

X_{i_db}: the initial moisture level of a sample, on a dry basis.

M_i (kg): Sample initial mass.

M_d (kg): Sample dried mass.

2.2.5. Assessment of the HCN concentration within the cassava root.

Three slices of cassava were used immediately after slicing in order to measure the root's initial HCN content. After soaking 12 cassava slices in one liter of water for 6 hours, 9 slices were used to dry and then three slices were used to measure HCN. Following the drying process, each of the 9 cassava slices was used to measure HCN. In accordance with reference [22], the HCN content of cassava slices was determined.

2.2.6. Drying procedure

Three values of the air temperature were used in three different experiments. For a specific drying air temperature, three cassava slices were set to dry at 1 m/s for air velocity, 10 % for air relative humidity, the air flow was made parallel to cassava sample surface. The moisture content at that moment was determined using equation (2), which involved measuring the mass of each cassava slice every 30 min. and averaging the 3 masses.

$$X_{db}(t) = \frac{M(t) - M_d}{M_d} \qquad (2)$$

DOI: 10.31695/IJASRE.2025.5.3

The variable X_{db} (t) refers to the moisture percentage of the sample measured on a dry basis at a particular time t; M(t) (kg) denotes the mass of the sample at that time, and M_d (kg) indicates the sample's dry mass. The corresponding value is employed to ascertain the final moisture content in accordance with equation (3) when the mass of the sample reaches a state of equilibrium.

$$X_{f\_db}(t_f) = \frac{M_f(t_f) - M_d}{M_d} \qquad (3)$$

Where

t_f (s): end of drying time.

X_{f_db}: final moisture content of a cassava sample, dry basis.

M_f (kg): the final mass of a cassava sample.

M_d (kg): the dry mass of a cassava sample.

For time values greater than t_f, the oven is set to 105 °C for 24 h, the mass of the dried sample is used for modeling the drying kinetic. The moisture content of cassava samples, wet basis, were calculated according to equation (4):

$$X_{wb}(t) = \frac{M(t) - M_d}{M_i} \qquad (4)$$

Where

X_{wb} (t): the humidity level of a sample at time (t), expressed on a wet basis.

M(t) (kg): the mass of the sample at time (t).

M_i (kg): the initial mass of the sample.

M_d (kg): the dry mass of the sample.

3. RESULTS AND DISCUSSION

3.1. The TRIZ technical systems

The drying process brings together many technical systems. A cassava slice can be considered as a technical super-system, containing a lot of technical systems bound together. A cassava technical system (CTS) is composed by an elementary quantity of water (E_1), an elementary quantity of HCN (E_2), and an elementary portion of solid cassava ($E_{2'}$). In that cassava technical system, the elementary quantity of water (E_1) has dissolved the elementary quantity of HCN (E_2) without need of a ‘facilitator’ or a ‘witness’, that is a TRIZ Vepole. The same elementary quantity of water (E_1) is also upholding the elementary portion of solid cassava ($E_{2'}$) by means of physical forces, without need of any ‘facilitator’ or ‘witness’, which is another TRIZ Vepole.

Once the drying operation is on, many technical systems can be observed in the form of TRIAD. The technical super-system is a TRIAD, composed of the dryer as facilitator (E_3), the drying air as active object (E_1) and the batch of cassava to dry as passive object (E_2). In that technical super-system, the dryer (E_3) helps the drying air (E_1) to heat the cassava batch (E_2). That technical super-system is composed by a lot of drying technical systems. A drying technical system (DTS) is also a TRIAD, composed by an elementary quantity of drying air (E_1), a cassava technical system (E_2) and the dryer (E_3). The elementary quantity of drying air (E_1) is the volume or mass of the drying air necessary for heating an elementary quantity of moisture (E_2) on an elementary portion of solid cassava. The dryer (E_3) provides an elementary volume of the drying room for hosting a cassava technical system (E_2). In a drying technical system, the elementary quantity of the drying air (E_1) heats an elementary quantity of liquid moisture (E_2), composed of water and

DOI: 10.31695/IJASRE.2025.5.3

HCN, inside the drying room (E_3) to accomplish three functions: vaporizing the moisture, up taking moisture vapor and moving it away.

3.2. The statement of the physical contradiction

The useful function in thin film drying of cassava samples is the elimination of HCN and the elimination of water in a technical drying system. In that technical system, the drying air is the component that needed two opposite values as far as its temperature is concerned. The physical contradiction is stated as follows: the drying temperature should be high to provide enough heat for the vaporization of liquid water and liquid HCN from cassava surface and the drying temperature should not be high to favorize the elimination of HCN upon the elimination of water.

3.3. The physical contradiction solution set

According to reference [12], HCN is produced by the hydrolysis of linamarin by the linamarase, at 37 °C, in the presence of water. The value of 37 °C is therefore considered as reference for drying temperature. Drying temperatures higher than 37 °C should be preferred in order to shorten the drying time. Unfortunately, temperatures above 72 °C lead to the denaturation of linamarase [12,23]. Reference [24] found that, from a heat consumption point of view, the elimination of HCN is more cost effective in the presence of water than in its absence. The solution to the physical contradiction above is stated as follows: "Set the drying temperature around 37 °C by upper values to promote the production and the elimination of HCN first, set it to higher values to promote the elimination of water then".

3.3.1. Inventive principle 15: Dynamization

Dynamization is the process of transforming a static drying condition set into a dynamic one. A drying process can be described as a dynamic problem that first requires a certain value of drying temperature to eliminate HCN and then a different drying temperature to eliminate water and shorten the drying process.

3.3.2. Inventive principle 34: Discarding and recovering

Since the vaporization of HCN goes along with the vaporization of water, we can decompose a drying operation into 2 periods. In the first period, a drying step is divided into a discarding sub-step during which HCN and water are eliminated; and a recovering one, during which the water is recovered and introduced to the drying room again. In the second period, there is no more HCN in the cassava, only water is eliminated; the recovering sub-step no longer exists.

3.3.3. Inventive principle 10: preliminary action

A preliminary action to the drying operation consists to introduce cassava slices into a large quantity of water, heated at 37 °C or above. The production of HCN is therefore ensured and an important quantity eliminated by solubilization as suggested by reference [4]. The selective elimination of the remaining HCN and the water is done by monitoring adequately the drying temperature in time.

3.3.4. Inventive principle 11: prior compensation

Since the elimination of HCN by vaporization goes along with the premature elimination of water, it becomes necessary to humidify a cassava slice by anticipation, increasing its water content by the quantity of water that will be lost during the removal of HCN. That is considered as a cassava slice water content prior compensation. The advantage of this solution is the possibility to conduct the drying operation at a high and single value for the temperature. This inventive principle is used in this work, as a consequence of inventive principle 10.

3.4. The physical characteristics of cassava samples

Table 1 presents the masses and the thicknesses of all the cassava samples for each drying temperature. Mean values of the initial masses M_i (kg) of cassava samples were found to be 32.7, 35.7 and 34 for T= 35 °C, T= 40 °C and T = 45 °C, respectively. In the same way, the mean values of the thicknesses e ($*10^{-3}$ m) of cassava samples were found to be 0.94, 0.88 and 0.88 for T= 35 °C, T= 40 °C and T = 45 °C, respectively.

DOI: 10.31695/IJASRE.2025.5.3

Table 1: physical characteristics of cassava samples

	T= 35°C		T= 40°C		T= 45°C	
	M_i (10^{-3} kg)	e (10^{-3} m)	M_i (10^{-3} kg)	e (10^{-3} m)	M_i (10^{-3} kg)	e (10^{-3} m)
Sample 1	36	95	35	0.86	31	0.87
Sample 2	33	89	33	0.94	34	0.99
Sample 3	29	98	39	0.84	37	0.79
Mean value	32.7	94	35.7	0.88	34	0.88

3.5. The HCN content of the cassava root

The initial HCN content was 86.28 ± 1.5 mg HCN/kg. According to reference [25], the concentration of HCN in the cassava root used in this work is more than 50 mg HCN/kg fresh cassava root; this root is believed to come from a bitter variety of cassava. Previous work found different values for the HCN content in cassava roots: 114 mg HCN/kg [26], 1090 mg HCN/kg [12], values between 104 and 1040 mg HCN/kg [25]. TRIZ Inventive Principle 10 was used to generate and eliminate a significant amount of HCN as a preliminary measure. The HCN content of cassava samples after six hours in water was 29.14 ± 0.8 mg HCN/kg. Although 66.22% of the initial HCN content in the root was removed by solubilization, the residual value was still more than 10 mg HCN/kg, the acceptable limit set by reference [27].

3.6 Cassava samples initial moisture content

The average of cassava root initial moisture content, wet basis, were found to be 62.33 ± 3.13 %, 65.59 ± 1.92 % and 65.69 ± 3.35 % for T= 35 °C, T= 40 °C and T = 45 °C, respectively. We obtain its values greater than 50 %, the variety of cassava used in this work should be considered as a high moisture content food-crop [28,29]. Many other research work found different values previously, ranging from 59 % to 70 % [25]. The mean values of the initial moisture content of the cassava root, dry basis, were found to be 1.67 ± 0.22, 1.91 ± 0.17 and 1.93 ± 0.28 for T= 35 °C, T= 40 °C and T = 45 °C respectively. Similar values were found previously in the literature [30,31].

3.7 The influence of drying temperature

The final values of samples of moisture content of samples were found to be 12.62 ± 2.70 %, 10.44 ± 2.23 and 10.77 ± 2.04 % for T = 35 °C, T = 40 °C and T = 45 °C, respectively. All those values ranged from 8 % to 15 %, used as reference for the conservation of dried cassava at ambient temperature [4,29,31]. HCN has a boiling point of 25.8 °C [32], which made it reasonable in this study to select higher drying temperatures of T = 35 °C, 40 °C, and 45 °C to assess the effect of temperature on the removal of HCN. Values of the final HCN content of cassava samples were found to be 7.23 ± 1.30 mg HCN/kg, 6.42 ± 2.4 mg HCN/kg and 8.06 ± 1.1 mg HCN/kg of fresh cassava root for T = 35 °C, T = 40 °C and T = 45 °C, respectively. All those values are less than 10 mg HCN/kg, the maximum admissible value set by reference [27] for human consumption. The drying operation ended after 2 h 30 min., 2 h and 1 h 10 min. for T = 35 °C, T = 40 °C and T = 45 °C respectively. Cassava roots rote 48 h after harvesting [28]. All the drying times recorded in this work were far below 48 h, the 3 drying operations were therefore successful. Elevating the drying temperature to 40 °C, increasing it from 35 °C by 5 °C, is advisable. It helped shorten the drying time by 30 minutes, while increasing it from 40 °C to 45 °C helped shorten the drying time by 50 minutes. All the drying times were less than 12 h, the vitamin C, niacin and riboflavin are not destroyed during the drying operation [10,14]. Reference [33] conducted an experiment in 2020, where they dehydrated cassava chips with dimensions (3 cm x 2 cm x 1 cm) and (0.8 cm x 0.6 cm x 0.4 cm) at 60 degrees Celsius for 18 h and 14 h respectively. The findings revealed that the cyanide content in the dried chips was well within the safe upper limit, and the chip size did not influence the appearance or the product's quality. Unfortunately, the study failed to disclose the initial and final hydrogen cyanide content of the cassava samples. By the way, although it is well known that all varieties of cassava contain cyanogenic

DOI: 10.31695/IJASRE.2025.5.3

compounds and therefore can produce hydrogen cyanide, many drying works reported in the literature did not care about its elimination [28].

3.8 Drying kinetics

Figure 1 presents the drying kinetics of cassava samples for T= 35 °C, T= 40 °C and T= 45 °C; relative humidity of 10 %, air velocity of 1 m/s; and parallel air flow. A drying kinetic was obtained for a specific value of dry air temperature which represent cassava samples moisture ratio versus time.

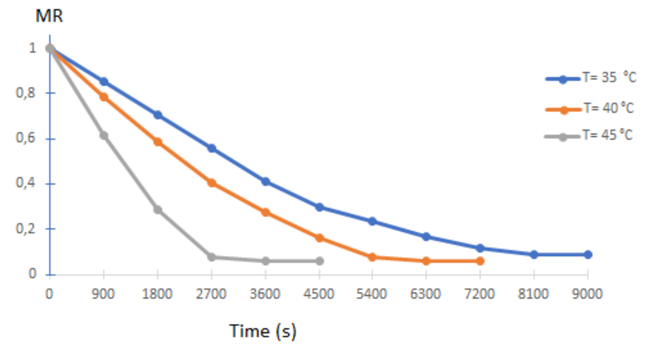

Figure 1 : Drying kinetics for V = 1 m/s; Rh = 10 %; parallel air flow

We obtain two parts of drying kinetics: in the first one, the moisture ratio of each sample decreased with time, while in the second part, it remained constant.

3.9 Mathematical modeling of drying curves

The drying data obtained for different values of temperature were fitted by Newton model and Wangh and Singh model. The models were evaluated using R^2, root mean square error (RMSE) and reduced chi-square ($□^2$) metrics. The ability of a theoretical model to describe the drying behavior of cassava samples for different values of temperature was based on the highest value of R^2, the lowest value of $□^2$ and the lowest value of RMSE. The values of the coefficient of determination, denoted as R^2, were observed to be: 0.9979; 0.9982; and 0.9951 for the Newton model, while the Wangh and Singh model yielded values of 0.9935; 0.9950; and 0.9970 corresponding to the drying temperatures of 35 °C, 45 °C, and 45 °C, respectively. All values obtained are above 0.9, which means a good correlation between experimental and theoretical data for all three temperature values. Similar results on the coefficient of determination have been reported in the literature for various food products with different temperatures and different air velocities [34,35,36,37]. Values of chi-square (□2) were: 1.75*10-2; 1.36*10-2 and 1.26*10-2 for the Newton model and 5.5*10-3; 4.8*10-3 and 1.7*10-3 for Wangh and Singh model at drying temperature of 35°C, 40°C and 45°C respectively. The chi-square values (□2) obtained using the Wangh & Singh model were ten times lower than the values obtained using the Newton model, showing better agreement with the experimental results. The chi-square values (□2) determined by reference [36] when drying pretreated cassava chips ranged from $8.94*10^{-2}$ to $13.33*10^{-3}$. They were better than those obtained with the Newton model, but the Wangh and Singh model gave the best results. The values of RMSE were: $11.84*10^{-2}$; $10.08*10^{-2}$ and $8.69*10^{-2}$ for the Newton model and 6.63*10-2; $6.01*10^{-2}$ and $3.19*10^{-2}$ for the Wangh and Singh model. At lower values, the Wangh and Singh model fitted the experimental results better.

4. CONCLUSION

The TRIZ separation in time method was used to work out an effective way of choosing the value of the air temperature in thin-layer drying process of cassava roots slices from bitter varieties. By so doing, it became possible to eliminate the cyanogenic compounds that make cassava toxic and unpalatable and to preserve thermo-sensible substances like vitamin C, niacin and riboflavin. The effective elimination of the hydrogen cyanide was done in two steps. In a preliminary action the hydrogen cyanide was eliminated by solubilization in water. In a second step, it was eliminated by vaporization during drying. Values of the residual hydrogen cyanide in cassava slices were less than 10 mg HCN/kg, the maximum admissible value set by reference [27] for human consumption.

DOI: 10.31695/IJASRE.2025.5.3

ACKNOWLEDGEMENTS

This work was supported by the Institut de la Francophonie pour le Développement Durable (IFDD/Canada)/Projet de Déploiement des Technologies et Innovations Environnementales (PDTIE)/Projet d'Excellence en Production d'Innovations Technologiques en Agro-Industries de l'Université de Ngaoundéré (PEPITA-UN) funded by the Organisation Internationale de la Francophonie (OIF), the Organisation of African, Caribean and Pacific States and the European Union (EU) (FED220/421-370)

AUTHORS CONTRIBUTION

Dr. Philémon DOUA and prof. Laurent BITJOKA work on bitter cassava in the framework of the ''Projet d'Excellence en Production d'Innovations Technologiques en Agro-Industries de l'Université de Ngaoundéré (PEPITA-UN) (Cameroun)''. For this paper, experiments were conducted by Philemon DOUA and Prof. Laurent BITJOKA supervised them.

REFERENCES

[1] Nainggolan E. A., Banout J., Urbanova K. ''Recent Trends in the Pre-Drying, Drying, and Post-Drying Processes for Cassava Tuber: A Review.'' Foods 2024, 13, 1778.

[2] Li S. Cui Y., Zhou Y., Luo Z., Liu J., Zhao M. ''The industrial applications of cassava: Current status, opportunities and prospects''. Journal of Food Science and Agriculture, Vol. 97, pp. 2282-2290. http, pp. //dx.doi.org/10.1002/jsfa.8287. 2017

[3] Alamu E.O., Manda N., Ntawuruhunga P., Abass A., Maziya-Dixon B. ''Elite cassava clones (Manihot esculenta) grown in Zambia: effects of drying techniques on their chemical, functional, and pasting properties''. Front. Sustain. Food Syst. 7:1129779.

[4] Dresden D. ''Cassava: Benefits, toxicity, and how to prepare''
https://www.medicalnewstoday.com/articles/323756/

Retrieved on February 27, 2024

[5] Saravanan R., Ravi V., Stephen R., Thajudhin S., George J. ''Post-harvest physiological deterioration of cassava (Manihot esculenta) - A review''. Indian Journal of Agriculture, Vol. 86, pp. 1383-1390, 2016.

[6] Stewart G. ''Recommended Temperatures for Dehydrating Different Foods''
By Getty Stewart March 3, 2021April 15, 2021 https://www.gettystewart.com/author/getty-demo-website/
Retrieved on January 28, 2024.

[7] Kumar M., Singh S., Godara R.K., Singh D., Pathak D.V. ''Effect of Pre-Drying Treatments, Drying Methods and Storage of Dehydrated Mature and Ripe Ber Fruits cv Kaithali and Umran on Non-Enzymatic Browning.'' J. Agric. Technol., 4(2): 23-30 (2017) ISSN: 2348-4721.

[8] Adeyeye S.A.O., Ashaolu T.J., Babu A.S. ''Food Drying: A Review''. Agricultural Reviews. DOI: 10.18805/ag.R-2537

[9] Pornpraipech P., Khusakul M., Singklin R., Sarabhorn P., Areeprasert C. ''Effect of temperature and shape on drying performance of cassava chips''. Agriculture and Natural Resources. 51 (2017) 402-409.

[10] Erenturk S., Galaboglu M.S., Gultekin S. ''The effects of cutting and drying medium on the vitamin C content of rosehip during drying''. Journal of Food Engineering. Vol. 68, Issue 4, June 2005, Pages 513-518.

[11] Bradbury J.H., Cliff J., Denton I.C. ''Uptake of wetting method in Africa to reduce cyanide poisoning and konzo from cassava.'' Food Chem Toxicol., 2011 March, 49(3):539-42. doi: 10.1016/j.fct.2010.04.049. 2011.

[12] Nambisan B. ''Strategies for elimination of cyanogens from cassava for reducing toxicity and improving food safety''. Food and Chemical Toxicology. 49(1):690-693. 93, 2011.

DOI: 10.31695/IJASRE.2025.5.3

[13] Nnedimma N. ‘‘Thermostability of cassava linamarase’’. A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Master of Science, December, 2015.

[14] Idah P.A., Musa J.J., Olaleye S.T. ‘‘Effect of Temperature and Drying Time on Some Nutritional Quality Parameters of Dried Tomatoes’’. AU J.T. 14(1): 25-32 (Jul. 2010)

[15] Malakar S., Arora V.K., Munshi M., Yadav D.K., Pou K.R.J., Deb S., Chandra R. ‘‘Application of novel pretreatment technologies for intensification of drying performance and quality attributes of food commodities: A review.’’. Food Sci. Biotechnol. 2023, 32, 1303–1335

[16] Popescu M., Iancu P., Plesu V., Bildea C.S., Manolache F.A. ‘‘Mathematical Modeling of Thin-Layer Drying Kinetics of Tomato Peels: Influence of Drying Temperature on the Energy Requirements and Extracts Quality.’’ Foods 2023, 12, 3883

[17] Buzera A., Gikundi E., Orina I., Sila D. ‘‘Effect of Pretreatments and Drying Methods on Physical and Microstructural Properties of Potato Flour’’. Foods 2022, 11, 507.

[18] Kamal M.M., Ali M.R., Shishir M.R.I., Mondal S.C. ‘‘Thin-layer drying kinetics of yam slices, physicochemical, and functional attributes of yam flour’’. J. Food Process Eng. 2020, 43, e13448.

[19] Gadd K. ‘‘TRIZ for Engineers: Enabling Inventive Problem Solving’’. First Edition. © 2011 John Wiley & Sons, Ltd. Published 2011 by John Wiley & Sons, Ltd. ISBN: 978-0-470-74188-7.

[20] Altshuller G.S. ‘‘Creativity as an Exact Science’’. New York, NY: Gordon & Breach. ISBN 0-677-21230-5, 1984. USA

[21] Yao-Tsung K., Chia-Chen L., Li-Hui L. ‘‘A Contradiction-Based Approach for Innovative Product Design’’. MATEC Web of Conferences 68, 05001 (2016) DOI: 10.1051/matecconf/20166 ICIEA 2016.

[22] A.O.A.C. Official Methods of Analysis of A.O.A.C. INTERNATIONAL (2005). 18th Ed., A.O.A.C. INTERNATIONAL, Gaithersburg, MD, USA, Official Method 2005.

[23] Bradbury J.H., Denton IC. ‘‘Mild method for removal of cyanogens from cassava leaves with retention of vitamins and protein’’. Food Chem. 2014 Sep 1;158:417-20. doi: 10.1016/j.foodchem.2014.02.132., 2014.

[24] Cardoso A., Mirione E., Massaza F., Cliff J., Haque R. ‘‘Processing of cassava roots to remove cyanogens’’. Journal of food Composition and Analysis, 18:451 – 460 (2005).

[25] Nambisan B., Sundaresan S. ‘‘Effect of Processing on the Cyanoglucoside Content of Cassava’’. Journal of the Science of Food and Agriculture, 36(11):N.p., n.d.. 91. (2015).

[26] Jinnajar H. ‘‘Processing cassava into flour for human food’’. Food and Fertilizer Technology Center (FFTC). Postharvest PT 4(2): 4–17. (2003)

[27] WHO ‘‘Cyanogenic glycosides. In: Safety evaluation of certain food additives and contaminants’’. Geneva, World Health Organization, 74th. Meeting of the Joint FAO/WHO Expert Committee on Food Additives (WHO Food Additives Series 65). Available at: WHO Food Additives Series No. 65, 2012. Retrieved on January 28, 2019.

[28] FAOSTAT ‘‘Production/Crops: Cassava, Food and Agriculture Organization of the United Nations: Division of Statistics’’. UN Food and Agriculture Organization Corporate Statistical Database (FAOSTAT). 2017.

[29] Bimbenet J.J., Duquenoy A., Trystram G. ‘‘Génie des procédés alimentaires des bases aux applications, Ingénierie Te, Dunod ed, 2e edition 573 pages, 2007.

[30] Zhang B.G., Zhou Y.D., Ning W., Xie DB. ‘‘Experimental Study on Energy Consumption of Combined Conventional and Dehumidification Drying’’. Drying Technol., 25(3): 471–474. 128, 2007.

[31] Zidenga T., Leyva-Guerrero E., Moon H., Siritunga D., Sayre R.T. ‘‘Extending cassava root shelf life via reduction of reactive oxygen species production’’. Plant Physiology, 159: 1396-1407, 2012.

DOI: 10.31695/IJASRE.2025.5.3

[32] Tissot S., Pichard A. ‘‘Seuils de Toxicité aiguë ; Acide Cyanhydrique (HCN);’’ Rapport final. Ministère de l'Écologie et du Développement Durable. Ministère de la Santé, de la Famille et des Personnes Handicapées. Direction des Risques Chroniques Unité d'Expertise des Substances Chimiques (ETSC). Avril 2005. France.

[33] Mujaffar S., Lalla A. ‘‘Drying Behaviour Of Cassava (Manihot esculenta) Chips, The International Conference on Emerging Trends in Engineering and Technology (IConETech-2020), Faculty of Engineering, The UWI, St. Augustine | June 1st – 5th, 2020 77.

[34] Waghmare R.B., Perumal A.B., Moses J.A., Dharamacrishnan C.A. ‘‘Recent developments in freeze-drying of Foods’’. Innovative Food Processing Technologies, A comprehensive review, 2021, pages 82-89.

[35] Aviara N.A., Igbeka J.C., Nwokocha L. ‘‘Effect of drying temperature on physicochemical properties of cassava starch’’. International Agrophysics 24(3):219-225, 2010.

[36] Tunde-Akintunde T.Y., Afon A.A. ‘‘Modelling of Hot-Air Drying of Pretreated Cassava Chips’’. Agricultural Engineering International: the CIGR Ejournal. Manuscript 1493 Vol. August, 2009.

[37] Doymaz ‘‘Air-drying characteristics of tomatoes’’. Journal of Food Engineering 78: 1291– 1297, 2007.

DOI: 10.31695/IJASRE.2025.5.3