Nigerian Research Journal of Chemical Sciences **(ISSN: 2682-6054)**
Volume 11, Issue 1, 2023

PRODUCTION AND DETERMINATION OF THE DRYING PARAMETERS OF *SOLANUM ESCULENTUM* POWDER

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ABSTRACT

Farm produce spoilage is prevalent in Nigeria, especially *Solanum esculentum* (tomatoes), which is due to a lack of adequate means of preservation. Drying has been continually shown to be the most effective method for lowering microbial activity and enhancing the durability of food crops. Besides preservation, the benefits of ingesting powdery food as part of diet and the ease it brings to the food preparation process cannot be overemphasized. Hence, the production, determination of its drying parameters and the nutritional value of *Solanum esculentum* powder was the major focus of this research work. Using the bench-top laboratory Air Oven Dryer, drying parameters such as moisture content, critical moisture, drying time, drying rate and the quality of the produced tomatoes powder were determined. In this study, a comparison of the nutritional value analysis of the produced tomatoes powder was done with traditional sun drying processing. The initial and final moisture content of the tomatoes powder was 94.56% and 2% respectively while the final moisture content from the open-air sun drying was 10.42%. The overall results of analysis of the produced *Solanum esculentum* powder showed that the oven dried sample had better nutritional values compared to the sun-dried sample.

KEYWORDS: Critical moisture**,** drying curve, drying parameters, drying rate, tomatoes powder, *Solanum esculentum*, nutritional value

INTRODUCTION

Most food crops contain at least 80% water at harvest and are therefore highly perishable if stored for a long period of time in that state [1]. This can make essential nutrients, vitamins, and minerals in food crops that supply the human diet in high proportions unavailable. Water content

in food crops must be reduced to an acceptable level that inhibits microbiological activity after harvesting [2].

Solanum esculentum is a perennial crop that is cultivated almost throughout the world. It is one of the most popular vegetables due to its numerous health benefits and the range of products available in the market [3]. Tomatoes are high in moisture, with an average initial moisture content of around 90% or more [4]; it is difficult to preserve it without spoilage. Many drying techniques or methods are available. The most common is via air, in which heat is applied by convection, which aids to carry the vapour as humidity from the product. An example of this is sun drying. Sun drying is generally cheap and freely available, the product is often subjected to uncontrolled long drying periods, exposure to contamination, resulting in low-quality dried products [5]. Due to possible outbreak of food borne disease which is a challenge to food exposed to sun drying, modern drying methods which are carried out under controlled conditions were employed by farmers that could supply products with better quality. However, these modern drying methods are not only expensive but also highly energy intensive [6].

Drying is the removal of moisture, that is, reducing water activity from a product, which could slow down the pace of deterioration and maintain the quality [7]. It is also a process in which free water in the food is significantly reduced, thus leading to concentration of dry matter without damaging the tissue, wholesomeness and physical appearance of the food. Drying has been greatly proved as the most common techniques used to reduce microbiological activity and to improve the stability of moist materials. At the present time, consumption of dehydrated food has experienced a noticeable increase in its demand on the market [8]. The purpose of drying is not limited to prevent deterioration and increase shelf life, it reduces the shipping weight and volume which improves the handling and reduces the economic cost involved in transportation [9]. This can only be done by reducing their water content to a certain acceptable value. Solid drying is generally understood to follow two distinct drying zones, known as the constant-rate period and the falling-rate period. The two zones are demarcated by a break point called the critical moisture content [10]. At the beginning of drying, the food sample comes in contact with the thermal equilibrium of the drying chamber of the dryer after which the external moisture in the food sample begins to be removed. This is referred to as the constant drying rate. Drying at this stage is mostly influenced by the drying conditions such as relative humidity, air temperature and velocity. This stage continues until the critical moisture content is reached after which

falling rate period begins to the equilibrium moisture content [11]. These drying parameters alongside the drying rate and economics of the process are vital design factors considered in selection of dryer for a product. Moisture determination is a widely used fundamental analytical operation, which satisfies the technological, analytical, commercial and regulatory necessities in the processing, testing and storage of food products and is an index economic value, stability and nutritional quality of food products [12].

Most drying approaches are usually related to the quality evaluation of the material to assess the impact of the drying method on taste, color, nutritional functions, texture, and other sensory qualities of food [13]. Huenulaf conducted a study on functional and sensory analysis of tomatoes that were dried with a hybrid solar dryer, a direct solar dryer, and open-air drying [14]. Also, Hossain *et al*. found out that hybrid dryer produced tomatoes with better quality and that a 56.25% drying time savings could be achieved when compared with sun drying [15].

To the best of our knowledge, the production of powdered tomatoes is highly limited, and its drying parameters study is scarce. Therefore, the aim of this study is the production as well as the determination of the drying parameters and nutritional value of *Solanum esculentum* powder using the bench-top laboratory Air Oven Dryer. In the study, the nutritional value analysis of the tomato powder was compared to the traditional dry tomatoes done by sun drying.

MATERIALS AND METHODS

In this study, analytical grade reagents were employed. Petroleum ether, tetraoxosulphate (vi) acid, potassium sulphate, copper sulphate, acetone, oxalic acid, sodium hydroxide were sourced from Sigma-Aldrich. Standardized dye, phenolphthalein indicator, distilled water, methyl red indicator and boric acid indicator were used. The bench-top laboratory Air oven dryer (NHG-9035A), desiccator, crucible, soxhlex apparatus, and muffle furnace (TT-EF-12 Techmel, USA) were equally utilized.

Sample collection and preparation

The fresh samples *Solanum esculentum* were bought from Uchi market in Auchi. They were washed and divided into two parts, one part was oven dried at 60 °C for 9 h, while the other part was sun dried for 15 days. The initial weight of wet tomatoes placed in the oven was 150 g, then the weight of sample was recorded at 30 min interval with the aid of electronic weighing balance

until an equilibrium is attained. This was repeated for three (3) runs and the averaged weight is presented in Table 1. The dried samples were ground into powder and stored for further analysis.

Nutritional Analysis

Determination of Moisture Content

The moisture content was determined following the ASTM D2216 standard. Washed crucibles were oven dried at 105 °C for an hour to ensure total dryness. They were then transferred into the desiccator to cool for about 30 minutes. The crucibles were weighed on an electronic balance and the weight recorded as (W_1). About 5 g of ground samples were weighed into the dried pre-weighed crucible (W_2). The crucibles and the content were oven-dried at 105 °C for 4 h. The samples were removed from the oven and dried until a constant weight was obtained. After drying, the crucible was transferred into the desiccator to cool for about 45 minutes and weighed (W_3). This analysis was carried out in triplicate and the average value was recorded as moisture content (M.C) in equation 1:

$$M.C\ (\%) = \frac{(w_2 - w_3)}{(w_2 - w_1)} \times 100 \qquad (1)$$

Where,

W_1 = Weight of empty Crucible,

W_2 = Weight of empty crucible + sample before drying

W_3 = Weight of crucible + sample after drying (constant weight).

Determination of Lycopene Content

The lycopene pigment was extracted by dissolving 10 g of dried sample in 10 ml of acetone. The mixture was shaken at 140 rpm for 30 min and then centrifuged at 12000 rpm for 15 min. About 100 ml of acetone was added to the final volume of the supernatant solution. Finally, using spectrophotometer, lycopene content was determined by measuring the absorbance at 503 nm and taking the average. The lycopene content was calculated as in equation 2 [16]:

$$Lycopene\ content\ \left(\frac{mg}{100g}\right) = \frac{(31.206 \times \mathrm{A})}{\mathrm{W}} \qquad (2)$$

Where W is the Weight (g) extracted and A is Average absorbance at 503nm.

Determination of Ascorbic Acid

About 5 g of dried sample was added to 50 ml of oxalic acid. The solution was thoroughly mixed and filtered. 10 ml of the extract was titrated against the standardized dye. The pale pink colour persistence for 5-10 sec was considered as an endpoint and the new volume was recorded. Ascorbic acid content can be calculated as in equation 3 [17]:

$$Ascorbic\ acid\ content = \frac{(M \times D \times N)}{W} \quad (3)$$

Where, M represents the Titre value, D is Dye factor (0.1/ liter value), N is volume made up and W= Weight of sample.

Determination of pH Value

The pH value of the sample was estimated by a pH meter (Benchtop pH/ORP Meter, BEP-M210) that helps to measure the acidity degree of 50 ml of tomato juice. The pH meter comprises a glass electrode connected to a digital meter.

Determination of Ash Content

Clean crucible was pre-dried in an oven for 30 minutes at 100 °C to assure total dryness of the crucible. It was then transferred into the desiccator to cool for 30 minutes and weighed on an electronic weighing balance as W_1. About 5 g sample was weighed into it and weighed as W_2. It was placed in a muffle furnace for 4 hours and the temperature was slowly increased to 450 ˚C to avoid incomplete ashing. Samples were ashed until it became whitish in color. It was removed into the desiccator with a tong and cooled to room temperature for an hour. Sample was reweighed as W_3. The percentage ash was calculated as in equation 4 [18], and the average taken:

$$Ash\ Content\ (\%) = \frac{(W_3 - W_1)}{W_2 - W_1} \times 100 \quad (4)$$

$$\%\ Organic\ matter = 100 - \%\ Ash\ content \quad (5)$$

Determination of Crude Fat Content

Previously dried, fat free thimble was weighed as W_1. About 5 g of sample was weighed into the thimble and weighed as W_2. The thimble and the sample were carefully wrapped and tied. Washed and dried 500 ml round bottom flask was weighed as W_3. The flask was filled with the petroleum ether and the sample in ratio of 40:60 was place in the sample holder of the soxhlet

extraction apparatus. The flask was then placed on a heating mantle and the heat source was adjusted to allow it to boil gently at 102 °C. It was allowed to siphon over 5 hours. The condenser was detached and the thimble removed. Petroleum ether was distilled from the flask. The distilling flask containing the oil was air dried at 100 °C for exactly 5 minutes to remove the solvent residues in oil. This was put inside a desiccator to cool and the weight was taken as W_4. The percentage fat contained was determined thus using equation 6 [19]:

$$\text{Fat content } (\%) = \frac{(W_4 - W_3)}{(W_2 - W_1)} \times 100 \qquad (6)$$

Determination of Crude Fiber

The starch and the protein part of food were dissolved by boiling with acid and then with a very strong base (NaOH). The residue, which comprises cellulose and lignin, was washed, dried and weighed. The residue was washed and the weight was subtracted from the weight of the residue. About 3 g of defatted sample was weighed (W_1) into 250 ml beaker containing 200 ml of 0.125 M or 1.25% tetraoxosulphate (vi) acid. The mixture was heated in a steam bath at 70 – 90 °C for 2 hours. It was then allowed to cool. The cooled mixture was filtered using a muslin cloth over Buckner funnels. The residue was washed three times with hot distilled water to remove the acid and then put in a beaker containing 200 ml of potassium hydroxide. The mixture was heated as before over a steam bath for 2 hours. The solution was filtered and the residue washed three times with hot distilled water, then with petroleum ether and water. The final residue obtained was put in a clean pre-weighted (W_2) crucible and dried at 120 °C to a constant weight. The crucible with the oven dried sample was put in a muffle furnace and ashed at 550 °C for 30 minutes such that the sample became ash white. The crucible and its contents were removed from the furnace, cooled in a desiccator and reweighed (W_3). Percentage fiber was calculated as in equation 7 [20]:

$$\text{Fiber content } (\%) = \frac{(W_2 - W_3)}{W_1} \times 100 \qquad (7)$$

Determination of Crude Protein

The analysis of crude protein was determined using the Kjeldahl method [21]. This process involved 3 different stages namely; digestion, distillation and titration. A chemical mixture of 150 g of K_2SO_4 and 10 g of $CuSO_4$ was made. 1 g of sample and 10 g of chemical mixture was weighed into a 250 ml digesting tube. 12 ml of concentrated H_2SO_4 was carefully added to the

mixture. The digesting tubes containing samples were kept in a rack and digested for 30 minutes at 420 °C in a fume cupboard. After digestion, the samples were allowed to cool to room temperature for about 1 h. Exactly 80 ml of distilled water was then added to the digested samples. Then, 25 ml of diluted digested sample as well as 25 ml of NaOH were measured into a distillation tube. Distillation was carried out using 5 ml of Boric Acid and methyl red indicator. This process was stopped when the conical flask containing boric acid-indicator solution reached 100 ml mark. The distillate was titrated using HCl until the end point was reached. At this stage, the purple color obtained during distillation changed to dark yellow. The formula used for protein calculation was:

$$\text{Protein (\%)} = \text{\% Nitrogen} \times 6.25 \quad (8)$$

Carbohydrate Content Determination

The carbohydrate content of the sample was obtained by difference, that is, as the difference between the total summations of percentage moisture, fat, fiber, protein and ash as in equation 10 [22]:

$$\text{Carbohydrate (\%)} = 100 - (\text{\%moisture} + \text{\%fat} + \text{\%protein} + \text{\%fiber} + \text{\%ash}) \quad (10)$$

RESULTS AND DISCUSSION

The experimental result from the loss in weight of the tomatoes sample is present in Table 1. Using equation 1, the moisture content was calculated per time. Plotting the moisture content (M.C) with time resulted to the drying curve in Figure 1(a). The drying model equation tomatoes sample from the trendline is as in equation 11. The model is applicable considering the coefficient of determination (R^2) as 0.9974, thus moisture content can be predicted with time (t).

$$M.C = -1E\text{-}06t^3 + 0.0017t^2 - 0.7029t + 97.447 \quad (11)$$

Table 1: Experimental drying data of *Solanum esculentum* using Air oven dryer

Time (min)	Average Weight (g)	Moisture Content (%)	Rate of Drying (g/min)
0	150.00	94.56	0.5
30	147.00	79.0	0.5
60	147.00	64.4	0.5
90	146.70	49.1	0.5
120	146.25	34.6	0.5
150	145.80	24.8	0.43
180	145.50	16.2	0.36
210	145.05	10.5	0.29
240	144.00	7.5	0.22
270	141.75	5.5	0.1
300	138.75	4.0	0.05
330	134.25	3.3	0.023
360	125.70	3.0	0.01
390	112.80	2.8	0.007
420	98.10	2.5	0.003
450	76.35	2.2	0.001
480	53.40	2.0	0
510	31.50	2.0	0
540	8.16	2.0	0
570	8.16	2.0	0

From the drying curve Figure 1(a), the rate of drying was calculated by taking tangent to the curve at various points [23]. The plot of the rate of drying versus moisture content as seen in Figure 1(b) further reveals vital drying parameters of *Solanum esculentum*.

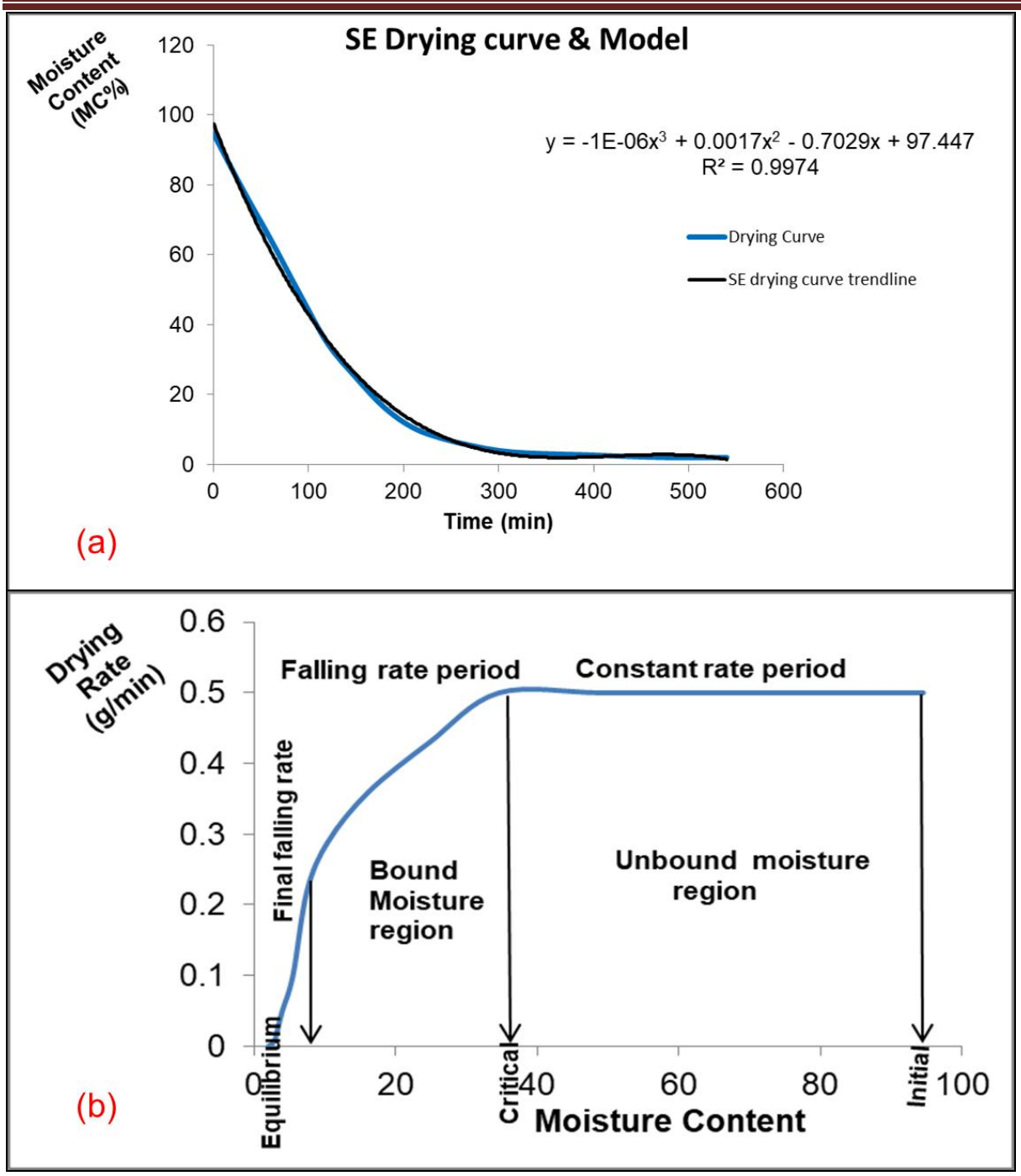
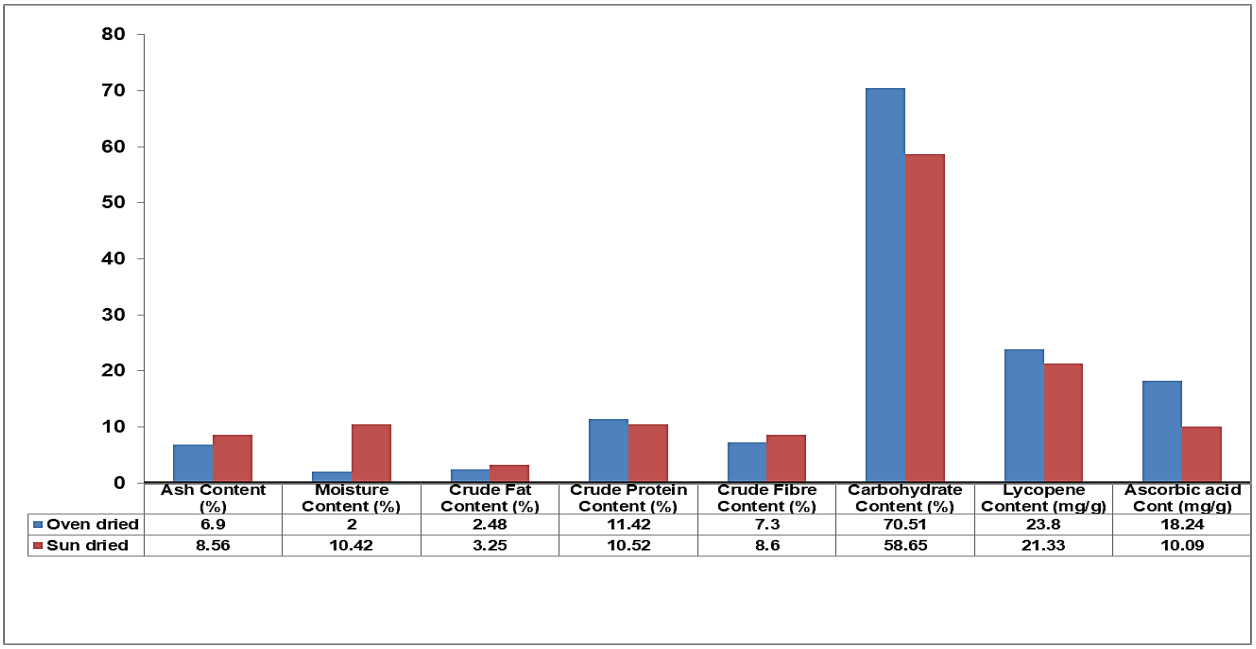


Figure 1: *Solanum esculentum* (SE) drying parameters (a) Drying curve and model (b) rate of drying curve with indicated drying parameters

From Figure 1(b), the equilibrium moisture content of *Solanum esculentum* was 2.0% which was achieved at 480 min. The drying rate of the sample was constant at the first 2 h, and this began to reduce for the next 4 h till a constant drying rate was noticed when the sample lost all its moisture. The rate of drying at constant period was gotten as 0.5 g of moisture per min and the

critical moisture content was gotten as 34.6%. The mechanism of drying in this region of unbound moisture content is basically evaporation [23]. After this point the mechanism changes which is noted in the falling rate. The first falling rate period commenced after 34.6% moisture content and ended at 7.5% moisture while the final falling rate period started at 7.5% moisture and ended at 2.0% moisture. The falling rate period is known as the bound moisture region and the drying mechanism involves diffusion before evaporation at the solid surfaces. The moisture content of the wet sample was 94.56% which enhances the microbial growth and spoilage of fresh *Solanum esculentum* [24]. With the final moisture content of the sample, it reduces microbial actions and makes it possible for products to be stored longer with increased shelf life.



	Ash Content (%)	Moisture Content (%)	Crude Fat Content (%)	Crude Protein Content (%)	Crude Fibre Content (%)	Carbohydrate Content (%)	Lycopene Content (mg/g)	Ascorbic acid Cont (mg/g)
Oven dried	6.9	2	2.48	11.42	7.3	70.51	23.8	18.24
Sun dried	8.56	10.42	3.25	10.52	8.6	58.65	21.33	10.09

Figure 2: Nutritional analysis of oven dried and sundried *Solanum esculentum* powder

Figure 2 shows the results of the nutritional composition of the tomato powders using two drying methods: oven drying at 60 °C for 9 h and sun drying for 15 days. The moisture content after the oven drying and sun drying was 2.0% and 10.42% for the oven dried and sun-dried tomato samples respectively. The moisture content of the sun dried tomato was higher than the oven dried tomato. It shows that the oven dried tomato powder with lower moisture content has a better shelf life. The sun-dry process cannot be controlled and there is possibility of re-absorption of moisture [25]. The sun-dried powder had an ash content of 8.56% while the oven dried sample was 6.90%; the sun-dried tomato recorded higher ash content. This shows that the

sun-dried sample had higher inorganic matter. The fat content for the oven dried and sun-dried tomato samples were 2.48% and 3.25% respectively. This shows that sun-dried samples had a higher fat content. The fiber content for the oven dried and sun-dried tomato samples were 7.30% and 8.60% respectively. This shows that sun-dried had higher fiber content. This may be as a result of the low heat energy derived from the sun. The protein value recorded for the oven dried and sun-dried tomato was 11.42% and 10.52% respectively. The result shows that the protein content of the oven dried tomato powder was higher. The carbohydrate content was determined by the difference between 100 and the total sum of the percentage of moisture, protein, fat, fiber and ash. The results obtained show that the oven dried sample was richer in carbohydrate than the sun dried sample. The lycopene content for the oven dried and sun-dried tomato sample was 23.80 mg/g and 21.3 mg/g respectively. It shows that the colour pigment in the oven-dried sample is higher than the sun-dried sample. The ascorbic acid content for the oven-dried and sun-dried sample was 18.24 mg/g and 10.09 mg/g. The results show that the oven-dried samples have much more vitamin C than the sun-dried samples.

CONCLUSION

Solanum esculentum powder was successfully produced using the bench-top laboratory Air oven dryer. In the procedure, vital drying process design parameters for tomatoes were established. The initial moisture content was determined to have 94.56% due to the effects of soil water which was accumulated by the fresh tomato. The drying rate at constant temperature was 0.5 g of moisture/min, the critical moisture content was 34.6%, optimal drying time was 480 min and the equilibrium moisture content was 2.0%. The drying and rate of drying curve show typical drying characteristics of solid materials [23, 26] with all notable features identified. In the comparative study of the nutritional value of the oven-dried and sun-dried tomatoes, it was observed that the moisture content of the oven-dried and sun-dried samples were 2% and 10.42% respectively. The time taken for the oven drying was very short for complete drying while the open air sun drying took about 2 weeks for complete drying. The drying rate is a function of drying time. Furthermore, oven drying produced tomato powder constituents with higher nutrients levels like protein, carbohydrate, ascorbic acid and lycopene content a better quality powder compared to the sun drying, which has more moisture, ash and crude fat contents. It is concluded that the use of controlled drying and production of tomato powder would help to preserve *Solanum esculentum* from spoilage and, in turn, wastage, and most notably, provide a nutritious source of food.

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