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ASSESSMENT OF THE PROCESSING EFFECTS OF FRESH SOLANUM ANGUIVI BERRIES ON BIOCHEMICAL CONTENTS AND FUNCTIONAL PROPERTIES OF POWDER

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ABSTRACT

Solanum anguivi is used as food and medicine for numerous health-benefiting effects. However, it is highly perishable due to its high moisture content. To avoid post-harvest losses, sun-drying is the common preservation method used from tropical countries. Unfortunately, this method faces uncomfortable applying during harvest period usually holding in rainy seasons. This study aims to investigate the effect the of oven-drying temperature (60, 80, and 100°C) combining with or not blanching (80 °C for 10 min) compared to the sun-drying on biochemical contents (moisture, crude fiber, polyphenol, alkaloid content) and functional properties (solubility, hygroscopicity) of *S. anguivi* berries processed into powder. The results exhibited excellent nutritional quality of *S. anguivi* powder processed from the oven-drying compared to the sun-drying. In addition, the increase in oven-drying temperature significantly affected all studied properties. Sun-drying resulted in long drying delay and powder with low polyphenol content. Moreover, blanching enhanced drying effect and resulted in powder having high polyphenol and fiber content but showing low solubility and hygroscopicity. Nonetheless, oven-drying berries at 80 °C for 24h without blanching proved to be the optimal condition leading to good quality powder which demonstrated high solubility and low hygroscopicity suggesting its good utilization and preservation as functional food ingredient.

Contribution/Originality: This study is one of the first that proposes the oven-drying process of S. anguivi berries as an alternative to sun-drying one traditionally used in households which greatly affects its overall quality. It simultaneously documents the biochemical quality attributes and the incorporation and preservation properties of the resulting powder.

1. INTRODUCTION

Solanum anguivi is a vegetable belonging to the plant family of Solanaceae. Commonly named *gnangnan* in Côte d'Ivoire, *S. anguivi* can be found in most non-arid regions of Africa (Elekofehinti, Kamdem, Kade, Rocha, & Adanlawo, 2013). The fruits which are berries are recommended as dietary staple and more especially as supplements for nursing mothers, the young, the aged, and anaemic patients, and also as therapeutics agent for various others diseases including diabetes and diabetes and artherosclerosis (Elekofehinti et al., 2013). In addition, these berries are commonly used in Ivory Coast diet as vegetable and also in malaria patient's diet because of their ability to stimulate appetite. In addition to its bitter taste, *S. anguivi* berries contain tiny amounts of sugar, but sufficient to provide a sweet aftertaste (Oyeyemi et al., 2015). Likewise, *S. anguivi* is a rich source of functional compounds such as polyphenols, alkaloids, fiber, vitamins and minerals (Abbe, Aboa, Ahi, & C., 2019; N'Dri et al., 2010) which provide it abundant biological properties including antioxidant, anti-inflammatory, cardiotonic, antihypertensive, antibacterial, analgesic, antidiabetic and laxative properties (Kandimalla, Kalita, Choudhury, & Kotoky, 2015). These properties are generally required in therapeutics especially against metabolic diseases such as hypertension and diabetes, which are growing significantly over the years. By the way, Africa currently yearly records over 16 million citizens suffering from diabetes in both young and old populations (International Diabetes Federation, 2019). Coping with such alarming trends, numerous prevention or healing strategies are usually spread out. However, drugs manufactured for this purpose remain insufficiently available and accessible to low-income populations. In addition, they have often demonstrated dramatic side effects. Therefore, the most appropriate measures requested are more preventive than curative and consist in regular physical practices and consumption of fruits and vegetables for their functional bioactive compounds (Sigal et al., 2013). In this context, the consumers' requests in safe foods are getting ahead and food industries are increasingly developing functional products to fit both nutrients and energy demands of human body and regulation of physiological pathologies. Consequently, they incorporate functional ingredients including prebiotics, probiotics and bioactive compounds to food system (Adefegha, 2018). These bioactive compounds include polyphenols and alkaloids that are endowed with beneficial antioxidant activities to the human body (Adefegha, 2018). With regard to its functional compounds, *S. anguivi* could be a prime vegetable in the formulation of functional foods. However, due to their high moisture content, *S. anguivi* like all vegetables are highly perishable and subjected to numerous post-harvest losses due to inappropriate preservation methods and structures (Mbondo, Owino, Ambuko, & Sila, 2018). In addition, these are seasonal commodities, which are highly available during the production period but are in severe shortage during other periods (Mbondo et al., 2018). Thus, one of the most effective means to address these issues would be to process them into powder. Powder provide advantage of reducing volume, facilitating handling, extending shelf life and therefore making food available over year (Caparino et al., 2012). Traditionally, the production of the powder requires sun-drying, which is difficulty to be applied during high production periods that stand in the rainy season in the production areas (Ngbede, Ibekwe, Okpara, & Adejumo, 2014). In addition, sun-drying can also cause biological and physical contamination (Arslan. & Ozcan, 2012). However, oven-drying offers the advantage of being faster and safer (Agiriga, Iwe, Etoamaihe, & Olaoye, 2015; Doymaz, Gorel, & Akgun, 2004). It can generally be combined or not with blanching. However, like all thermal unit operations, oven-drying showed a significant negative impact on the quality of the finished product (Betoret, Calabuig-Jiménez, Barrera, & Marco, 2016; Mbondo et al., 2018). They resulted in the degradation of inherent phenolic compounds and nutrients (vitamins etc), also the gelatinization of carbohydrates and the gelation of protein (Betoret et al., 2016; Dos Reis et al., 2015). These modifications in turn lead to direct change in functional properties such as solubility and hygroscopicity of derived products (Caparino et al., 2012; Nawaz, Shad, Mehmood, Rehman, & Munir, 2015; Tonon, Brabet, Pallet, Brat, & Hubinger, 2009). Furthermore, each vegetable possesses a specific matrix structure leading to its unique behaviour during processing (Betoret et al., 2016; Tunde-Akintunde, Oyelade, & Akintunde, 2014).

However, according to Mbondo et al. (2018) only few studies have investigated the drying characteristics of African eggplant products suggesting that there is lack of information on drying of African eggplant. To our knowledge, no studies have been devoted to determine the effect of drying methods coupled or not to blanching on the physic-chemical and functional properties of *Solanum anguivi.* Hence, the aim of the present work was to evaluate the physico-chemical properties, namely moisture content, ash content, fiber content, sugar content, polyphenol and alkaloid content) and functional properties, namely solubility and hygroscopicity under two drying methods, namely oven-drying combined or with blanching, compared to sun-drying of gnangnan powder in order to enhance it used as functional food ingredient.

2. MATERIALS AND METHODS

2.1. Plant Material and Samples Collection

The raw material investigated consisted in mature green berries of gnangnan (*S. anguivi*) produced from Ivorian lands. These berries were purchased from five raw foodstuffs sellers in Biankouma located in western Côte d'Ivoire at about 700 km from Abidjan and 456 km from Korhogo. After packaging in a perforated jute bag, berries were sent to the laboratory of Université Peleforo Gon Coulibaly in Korhogo by car. They were then spread on a tablecloth and covered until ripening (red and yellow colour). After washing in bleached tap water, they were rinsed with tap water prior to sorting for removing undesirable matters (rotten berries, seed coats, foreign matters). Thus, berries were gathered into nine sets by 900 g (300 g X 3 replicates) and submitted to different heating treatments.

2.2. Operating Conditions of Gnangnan Powder Processing

2.2.1. Evaluation of the Effects of Oven-Drying Temperature

To assess the effect of the drying temperature, 300 g of non-blanching berries were carefully spread in a thin layer on a stainless steel tray and placed in a convective oven which requested temperature was previously checked. The berries were then dried for 24 h at 60 °C and 80 °C and 8 hours at 100 °C Table 1. After drying, the dry berries were ground in a blender-grinder (Nasco) and then sieved using a 0.2 mm mesh sieve to get fine powder. The powder was then kept in a glass bottle coated with aluminum foil and hermetically sealed till further analysis for the optimal temperature providing most biochemical and functional traits. Each experiment was held in triplicate.

Table-1. Experimentation design of drying process of *S. anguivi* berries before powdered.

Drying methods	Temperature (°C)	Drying duration	Blanching (°C/min)
Oven	60	24 h	0
	80	24 h	0
	80	24 h	80 /10
	100	8 h	0
Sun	28 ± 5	11 days	0

2.2.2. Evaluation of the Effects of Drying Methods

The effect of the drying methods was evaluated using traditional sun-drying commonly used in households and oven-drying at the optimal temperature resulted from the investigation in section 2.2.1. For sun-drying, 300 g of pretreated non-blanched berries were carefully poured on a clean tablecloth laid out on a table at about 1.5 m from the ground. The table was placed under the sun for 11 days at the rate of 10 h per day. The air speed was 2 m/s at 32.5 ± 5 °C under 71% relative humidity. The oven-drying sample were processed as mentioned in section 2.2.1. Both samples powders were then investigated for biochemical and functional parameters. Each experiment was carried out in triplicate.

2.2.3. Evaluation of the Effects of Blanching Method

The blanching effect was evaluated by processing berries according to Dos Reis et al. (2015) and Egbuonu and Nzewi (2016). Thus, 300 g of pretreated berries were poured into small perforated plastic bags and immersed in water at 100 °C for 3 min in a hot water bath. These bags were held in water using light weight. After blanching, the berries were then drained, oven-dried at the optimal temperature resulting from section 2.2.1, then ground into gnangnan powder. Other 300 g of pretreated non-blanched berries were also dried and ground in the similar conditions and used as a control. Both gnangnan powder samples were analysed for biochemical and functional properties. Assays were also performed in triplicate.

2.3. Determination of Physicochemical and Functional Properties

2.3.1. Determination of Moisture Content

Moisture content (MC) was determined by gravimetric analysis using the method described by Akoto, Borquaye, Howard, and Konwuruk (2015). Two (2) g of *S. anguivi* powder was placed in a pre-weighed dish and then oven-dried at 105 °C to constant weight. The loss in mass at the end of drying was used to calculate the residual moisture content of the powder and then expressed as a percentage of the mass of the sample in beginning according to the following equation.

$$\mathrm{MC}(\%) = \frac{M_2 - M_0}{M_1 - M_0} \times 100$$

Where M_1, M_2 and M_0 are the mass in grams of dish containing sample before and after drying, and the empty dish.

2.3.2. Determination of Crude Fiber Content

As regards the crude fibre content (CFC), the AOAC (2000) method was used. Briefly, two grams of powder, previously diluted in 50 mL of sulphuric acid of 0.25 N, were boiled for 30 min under a reflux condenser. Then, 50 ml of NaOH solution (0.31 N) were added to the mixture and brought back to boiling for 30 min. After filtering the cooled resulted mixture on Whatman paper No. 4, the residue was washed with distilled water and then dried in oven (Memmert, Germany) at 105°C for 8 h. The dry matter is then incinerated in a muffle furnace (Pyrolabo, France) at 550°C for 12 h. The ash obtained was used to calculate the crude fiber content of the samples according to the following equation.

$$\mathrm{CFC\ (g/100gDM)} = \frac{M_1 - M_2}{M} \times 100$$

Where CFC denote to crude fiber content, M_1, M_2 are the mass in grams of sample before and after ashing, and M the dry matter of the sample.

2.3.3. Determination of Total Sugar Content

The total sugar content (TSC) was determined using the modified phenol-sulfuric colorimetric method of Dubois, Gilles, Hamilton, Rebers, and Smith (1956) after extraction according to the method described by Martinez-Herrera, Siddhuraju, Francis, Davila-Ortiz, and Becker (2006). The extraction consisted in pouring 0.5 g of powder into 10 ml of ethanol (80%, v/v) under vortexing. The tubes was immersed to boiling water bath for 90 min and then cooled under tap water. After centrifugation at 3000 rpm for 10 min, the supernatant was recovered and the pellet was washed once again with hot ethanol (80%). The supernatants were then mixed together. Subsequently, about 0.1 mL of supernatant was sampled and 0.9 mL of distilled water, 1 ml of 5% (w/v) phenol and 5 ml of concentrated sulphuric acid were successively added and vortexed. The tube was then let to stand 30 min. Then the absorbance was measured at 490 nm using a spectrophotometer (HITACHI) against a blank prepared in the same conditions with 1 ml of distilled without extract. The total sugar contents expressed as glucose equivalent were determined from a glucose calibration curve ($R^2 = 0.998$). The tests were performed in triplicate.

2.3.4. Determination of Total Polyphenol Content

The total polyphenol content (TPC) was determined using the Folin-Ciocalteu method described by Mbondo et al. (2018) with some modifications. The polyphenols were previously extracted by dissolving 2g of the powder in 20 mL of 70% hydromethanolic solution and vortexed for 3h. The mixture was then centrifuged at 1000 rpm for 10 min using a SIGMA centrifuge. The pellet was extracted again and then the all supernatants were mixed together in a 50 mL tube. Subsequently, to 1 mL of the sampled supernatant, 1 mL of 10% (v/v) Folin-Ciocalteu reagent and 2 mL of 20% sodium carbonate solution are successively added. The mixture is then adjusted to 10 mL with distilled water and vortexed. After an incubation for 1h, the absorbance of the mixture was read at 765 nm using the HITACHI spectrophotometer against a blank prepared under the same conditions without extract. The concentration of total polyphenols was determined from a calibration curve performed with gallic acid at different concentrations and expressed to g GAE/100g dry matter.

2.3.5. Determination of Total Alkaloid Content

Total alkaloid content (TAC) was determined using the method described by Harborne (1973). To be done, 5g of the powder was dissolving in 200 mL of ethanol solution containing 20% acetic acid and allowed to stand for 4h. After vacuum filtration, the filtrate was concentrated in a sand bath up to 50 mL to which was gradually added a concentrated ammonia solution until a yellow-orange precipitate was obtained. This precipitate was recovered by filtration and then oven-dried at 80°C until constant weight. The total alkaloid content expressed as g/100g dry matter was calculated using the following formula.

$$\text{TAC (g/100gDM)} = \frac{m_1 - m_2}{m} \times 100$$

Where m_1 and m_2 denote to the mass (g) of the precipitate before and after drying, m is the mass (g) of dry matter of the sample.

2.3.6. Determination of Water Solubility

Water solubility index (WSI) of *S. anguivi* berry powder was determined using the improved method of Tonon et al. (2009). Briefly, 2g of powder was diluted in 50 mL of distilled water under magnetic agitation for 5 min. After centrifugation at 3000 rpm for 15 min, 20 mL of the supernatant was transferred to a dish and dried at 105°C for 5h. Solubility was obtained using the equation below and then reported on a dry basis.

$$\text{WSI (g/100g dm)} = \frac{M_2 - M_1}{M_e} \times 100$$

With M_2, the mass of dish and sample after drying, M_1, the mass of empty dish and M_e, the mass of dry matter of the sample.

2.3.7. Determination of Water Hygroscopicity

The water hygroscopicity index (WHI) was determined using the method of Tonon et al. (2009) with some modifications. To be done, A Petri dish containing 1g of powder was incubated at 22°C with 500 mL of 75% saturated NaCl solution in a hermetically sealed jar until constant weigh of petri dish was reached. WHI, expressed as g of adsorbed moisture per 100 g of dry matter, was calculated according to the following equation:

$$\text{WHI} = \frac{m_2 - m_1}{m_{dm}} \times 100$$

Where m_2 and m_1 denote to mass of petri dish before and after incubation and m_{dm} is the dry matter.

2.4. Statistical Analysis

All experiments were carried out in triplicate and the data were analysed using Statistica software (Statistica version 10). The statistical treatment consisted in student t-test and one way analysis of variance followed by Newman-Keuls comparison post-hoc test as appropriate at 5% significance. The means and standard deviations and graphical draws were presented using Microsoft Excel 2013.

3. RESULTS

3.1. Effect of Oven-Drying Temperature on Physicochemical and Functional Properties of S. Anguivi Berries Powder

The effect of oven-drying temperature on the physicochemical characteristics of non-blanched berries powder is depicted in table 2. The results highlight a significant effect of the increase in drying temperature ($P<0.05$) on most biochemical characteristics of *S. anguivi* berries powder. The increase in oven-dried temperature leads to the quite decrease (90.68%) of moisture content from 60 °C to 80 °C following by a low decrease (31.81%) from 80 °C to 100 °C. The averages of moisture content of the berries powders are ranged from 3.0% (100 °C) to 47.2% (60 °C). However, the oven-drying at 100 °C for 24 h results in completely charred berries. As far as concerned crude fiber, the values present significant variation ($P<0.05$) as given in table 2. The highest content is recorded from the berries dried 80 °C (51.75±0.35 g/100gDM), followed by 100 °C (39.25±0.26 g/100gDM) and the lowest value is provided by oven-drying at 60°C (27.50±0.10 g/100g DM). In addition, the increase in oven-drying temperature results in an increase of the total sugars (TSC) and polyphenol (TPC) contents. This increase is 78.51 and 14.18% for TSC and 74.48% and 19.63% for TPC respectively between 60 °C and 80 °C and between 80 °C and 100 °C. However, the increase in temperature does not present any obvious change in the TAC ($P>0.05$) of *S. anguivi* berries powder, with values oscillating between 0.8±0.02 and 0.9±0.06 g/100g DM Table 2.

Table-2. Biochemical contents of *S. anguivi* berries powder after oven-drying at various temperatures.

Parameters	60 °C	80 °C	100 °C	80 °C
	Non-blanched berries powder			Blanched berries powder
Moisture content (%)	47.2 ±2.55^{a}	4.4±0.11^{b}	3.0±0.15^{c}	1.6±0.05^{d}
Crude fiber content (g/100g DM)	27.50±0.10^{d}	51.75±0.35^{b}	39.25±0.26^{c}	58.5±0.10^{a}
Total sugar content (g/100g DM)	0.26±0.01^{d}	1.21±0.06^{b}	1.41±0.04^{a}	0.84±0.02^{c}
Total polyphenol content (mg GAE/100g DM)	36.82±0.91^{d}	144.27±0.81^{c}	179.50±0.81^{a}	170.14±0.69^{b}
Total alkaloïd content (mg/100g DM)	0.91±0.06^{a}	0.80±0.02^{a}	0.8±0.02^{a}	0.50±0.04^{b}

Note: Values are mean ± standard deviation. Values with different letters per line are statistically different at 5%significance.

Regarding functional properties, water solubility and water hygroscopicity indexes were studied and presented in figure 1. The increase in temperature from 60 °C to 80 °C resulted in a highly significant increase ($P<0.001$) in the solubility and hygroscopicity of the berries powders of about 701% and 259%, respectively. However, further increase in temperature from 80 °C to 100 °C led to a significant ($p < 0.05$) decrease of 27% for solubility and 36% for the hygroscopicity. The respective values of water solubility and hygroscopicity indexes were 8.25±1.2 and 5.85±1.1 g/100g DM at 60 °C, 66.1±1.14 and 21.05±1.3 g/100g DM at 80 °C, and 48.09±0.88 and 13.1±0.9 g/100g DM at 100°C.

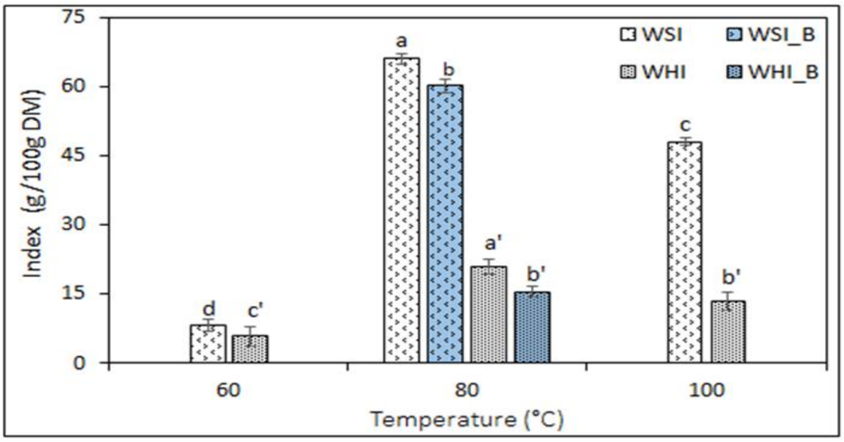

Figure-1. Effect of oven-drying temperature and blanching on the solubility and hygroscopicity of *Solanum anguivi* powder, WSI and WSI_B denote to water solubility index of non-blanched and blanched berries powder, WHI and WHI_B denote to water hygroscopicity index of non-blanched and blanched berries powder, bars with different letters are statistically different at 5%significance.

3.2. Effect of Blanching on Biochemical and Functional Properties of S. Anguivi Powder

The effect of blanching on biochemical characteristics of oven-dried *S. anguivi* berries powders at 80 °C for 24 h is presented in table 2 showing that the blanching results in significant changes ($p < 0.01$) for each dependent variable. Blanched berries powders induced a decrease in moisture, total sugar and total alkaloids contents and an increase in crude fiber and total polyphenol contents. The decrease in moisture, total sugar and total alkaloids contents of blanched berries powders are respectively 2.75, 1.44 and 1.6 times lower than those of non-blanched ones; while the crude fibers and total polyphenols increase with rate of 13.04% and 17.93%, respectively. However, the blanching leads to a significant decrease in water solubility and hygroscopicity indexes ($p < 0.01$) of the berries powder as shown in Figure 1. The decrease rate is about 8.9% for the solubility and 25.9% for the hygroscopicity.

3.3. Effect of the Drying Method on Biochemical and Functional Properties of S. Anguivi Berries Powder

The effect of the drying method is evaluated using oven-drying at 80 °C for 24 h and sun-drying at 32.5±5°C for 11 days and presented in table 3. The biochemical characteristics of non-blanched berries powders are significantly affected by the oven-drying and sun-drying ($P < 0.05$). Compared with oven-dried berries powders, sun-dried berries powder is about twice humid (8.7%) and shows 1.4 time higher total alkaloid content. Moreover, sun-dried berries powders contain approximately 1.1 and 1.7 time lower crude fiber and total sugar contents respectively than oven-dried berries powders. However, the sun-dried berries powders display drastically lower polyphenol content and also ash loss of 60.6%. Figure 2 shows the comparative effect of oven- and sun-drying method of water solubility and hygroscopicity indexes of non-blanched berries powders. The results indicate that sun-dried berries powders have lowest water solubility and hygroscopicity compared with the oven-dried ones ($p < 0.001$). The decrease magnitude are 21.1% and 22.8% for the water solubility and water hygroscopicity, respectively.

Table-3. Biochemical characteristics of non-blanched *S. anguivi* powder with respect to drying methods.

Biochemical parameters	**Sun drying**	**Oven drying**
Moisture content (%)	8.7 ± 0.14^{a}	4.4 ± 0.11^{b}
Crude fiber content (g/100g DM)	46.5 ± 0.71^{b}	51.75 ± 0.35^{b}
Total sugar content (g/100g DM)	0.7 ± 0.01^{c}	1.20 ± 0.10^{a}
Total polyphenol content (mgGAE/100 g DM)	57.12 ± 0.81^{c}	$143.77 \pm 0,81^{b}$
Total alkaloïd contents (g /100g DM)	$1.1 \pm 0,14^{a}$	0.8 ± 0.04^{b}

Note: Values with different letters on line are statistically different at 5% significance

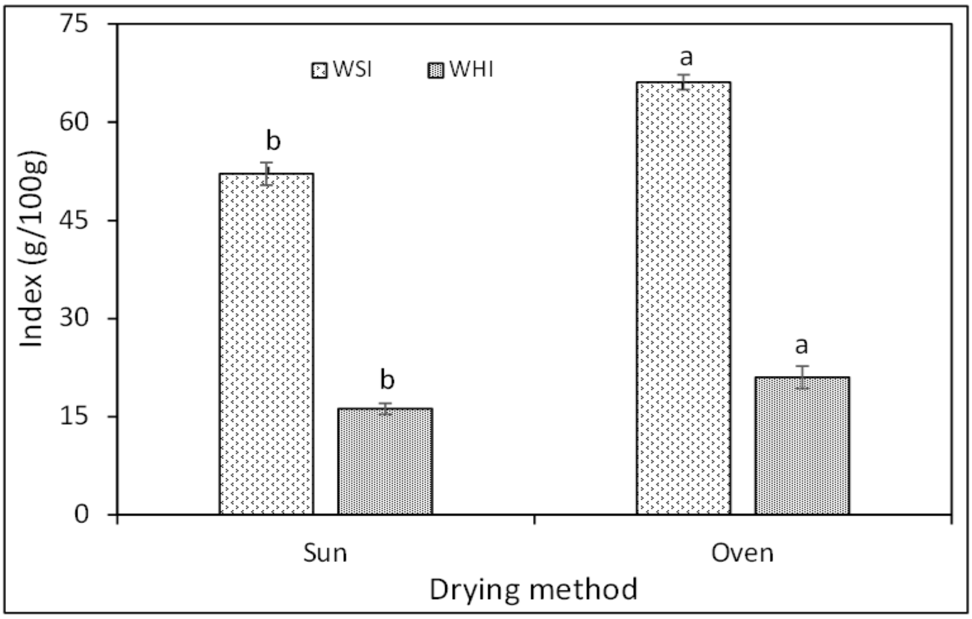

Figure-2. Effect of drying method on solubility and hydrophobicity of non-blanched *Solanum anguivi* powder.

Oven-drying were carried out at 80 °C for 24h and sun drying were performed for 11 days, WSI and WHI denote to water solubility index and water hygroscopicity index respectively, bars with different letters are statistically different at 5% significance.

4. DISCUSSION

Solanum anguivi is of the most appreciated vegetables for its numerous traditional known therapeutic and nutritional properties. However, its perishability due to the high moisture content led to its unavailability on the market during off-production periods. For finding efficient preservation methods, the sun-drying commonly used as traditional household drying process from tropical lands and the oven-drying as a modern one were studied. From the three oven temperatures applied, the berries' drying was earlier and most effective at 80 °C and 100 °C for getting powder and thus preserving products over seasons.

This could be explained by the rapid water removal from the product due to the high calorific energy accumulated inside. The higher the drying temperature the greater and faster the water removal trend leading to a low residual water content (Arslan & Ozcan, 2010). Thus, the berries are more friable and provided true powder, highly stable and water soluble but seeming less hygroscopic. These results are in consistent with the work of Derradji-Benmeziane (2015) who dried fresh grapes at different temperatures. In addition, the high solubility shown at high temperature could be related to the softening of the matrix structure of berries (Dan, 2015; Nawaz et al., 2015). According to Caparino et al. (2012) higher water solubility index (WSI) could be linked to significant disaggregation degree in macromolecules of the raw product as affected by drying process and condition. Indeed, Tonon et al. (2009) reported an increase in the water solubility of *Euterpe oleraceae* Mart. powder produced with different carrier agents resulting from the structural disruption at high temperature.

In addition, hygroscopicity defined as food capacity to attract water molecules in contact with the surrounding air, has increased and then decreased over 80 °C, may be due to the degree of modification of inherent macromolecules in the berry powder. According to Tonon et al. (2009) the hygroscopicity is linked to the number of hydrophilic groups. Thus, it seems that high temperature resulted in the gelatinization of carbohydrates and the denaturation of proteins which may have modified the loads of these macromolecules involved in water adsorption. However, the hygroscopicity value mentioned from this study is comparable to the records of Caparino et al. (2012) and Tonon et al. (2009).

Furthermore, polyphenols and total sugars content increased with the increase of the oven-drying temperature in accordance with the low moisture content of powders observed at 80 °C and 100 °C (Vega-Gálvez et al., 2009). Moreover, the destabilization of berries texture at high temperature could promote proper extraction and release of these functional compounds previously bound to other molecules and their isomerization (Vega-Gálvez et al., 2009). On the other hand, oven-drying at 60 °C resulted in a granular pastry with high moisture content (about 50%) which did not enable any significant extraction of bioactive compounds due to the presence of larger particles. Nevertheless, total polyphenol content in this study are similar to those reported by Mbondo et al. (2018) who dried various African eggplants.

In addition, as the results observed in this study, Dan (2015) have recorded low sugar content in ripening *S. anguivi* berries powder. According to the author, low sugar content could be explained by a small amount of starch in the nutritional composition of berries. On the other hand, crude fiber content increased in about 50% with the increase in temperature from 60°C to 80°C. However, the lowest TFC value was 27.6 g/100g DM. The lowest total fiber content were reported by Akoto et al. (2015) on *S. torvum* dried berries powder at 60°C (4 g/100g DM). This difference may be attributed to varietal diversity that influences the biochemical properties of plant species (Agiriga et al., 2015; Sharma et al., 2015). From the observations of the effect of temperature on the properties of the powders, it appears that drying at 80°C would offer a final product with better biochemical and functional properties.

The effect of the drying methods was evaluated between oven-drying which is based on a convective transfer of energy and the most widespread industrial method, and sun-drying traditionally used in rural areas and based on solar radiation transfer.

The results showed that sun-drying resulted in high moist powders with lowest biochemical and functional properties. Sun-drying was slow and took eleven times as long. According to Arslan. and Ozcan (2012) sun-drying resulted in longer time due to the low and fluctuating temperature during the drying process. Additionally, sun-drying presented the disadvantage of exposing the berries to both health hazards (uncontrolled occurrence of dust and insects, growth of pathogenic microorganisms etc.) and likewise weather fluctuations (rain and low solar radiation) (Arslan. & Ozcan, 2012; Doymaz et al., 2004).

In addition, the decline of total sugar and total polyphenol content during sun-drying process may be attributed to the long exposure time of non-blanched berries to air at a lower temperature (25°C) leading to the oxidation and the degradation of biochemical compounds resulting from both oxygen reactions on the compounds and enzymatic browning due to polyphenoloxidase and pereoxidases (Mbondo et al., 2018; Vallejo, Tomás-Barberán, & García-Viguera, 2003).

Moreover, Polyphenols which contribute to many health benefits including cardiovascular disease and neurodegenerative diseases in humans were found to decrease with sun-drying. Similar reduced total polyphenol content were reported by Sangwan, Kawatra, and Sehgal (2010); Bachir Bey, Richard, Meziant, Fauconnier, and Louaileche (2017) and Managa, Sultanbawa, and Sivakumar (2020) using sun-drying on onion powder, fig and *Solanum retroflexum Dun* respectively.

However, Arslan and Ozcan (2010) indicated that the polyphenol content significantly differs from the dried sun and oven samples when the oven-drying temperature was above 70°C. According to Nguyen (2015), oven-drying process would be an advantageous method in the processing of fruits and vegetables due to a shorter heat exposure time and the control of operating conditions such as the reproducibility of drying, the limitation of physical and biological contamination. Moreover, sun-drying led to high total alkaloid content. Similar results are reported by Irondi, Anokam, and Ndidi (2013) when sun and oven-drying papaya seeds. Authors attributed sun-drying increase of alkaloid content to the fact sun-drying allowed the retention of both non-volatile and volatile alkaloids.

Blanching was mainly used to inhibit food spoilage enzymes but can also promote the maintenance of sensory properties, the softening of food matrix and can eliminate occlusive gases. In this study, the effect of blanching prior to oven-drying *S. anguivi* berries significantly affected both biochemical content and functional properties. Blanched berries powders showed higher moisture content and crude fiber and polyphenol contents but with lower sugar contents and total alkaloids in comparison with non-blanched ones. The low moisture content and the increase in crude fiber and total polyphenols could be explained by the fact that the blanching have exacerbated the water transfer from berries and the leaching of the phenolic molecules resulting from its softening effect of food matrix (Arslan. & Ozcan, 2012; Blessington et al., 2010).

In addition, the increase in crude fiber and the decrease in total sugar content during blanching may be attributed to the gelatinization of carbohydrates enhanced by blanching related to the severely thermal treatment (Agarry, Ajani, & Aremu, 2013; Agiriga et al., 2015). Indeed, fiber is defined as non-digestible carbohydrates plus lignin and known to cleanse the digestive tract, to eliminate potential carcinogens from the body and to control blood sugar (Gbadamosi, Famuwagun, & Nnamezie, 2018).

However, with regard to effect of blanching on total polyphenol contents, contradictory results are reported in the literature regarding. Bamidele, Fasogbon, Adebowale, and Adeyanju (2017) and Meena, Agrawal, and Agrawal (2016) pointed out a decrease in phenolic compounds in leafy vegetables after blanching while Heras-Ramírez et al. (2012) suggested the increased in polyphenol content after potato blanching. It can then be concluded that the effect of blanching on the polyphenol contents could be linked to the types of treated plant organ. Thus, the increase in polyphenol content in this work could be result from the additional thermal effects that release phenolic molecules and their isomerization as previously described.

However, the decrease in total alkaloid content after blanching was observed in this study. Similar results were reported by Egbuonu and Nzewi (2016) and Yusufu and Obiegbuna (2015) after blanching of bitter yam and bitter vegetable leaves respectively and by Abeshu and Kefale (2017) after boiling lupin kernels. These authors indicated that alkaloids are thermolabile compounds.

Thus, their reduction may be resulted from their degradation caused by the additional thermal effect of blanching compared to non-blanched berries powders. In addition, blanching of berries prior to oven-drying led to the decrease in powder solubility and hygroscopicity indexes. Gbadamosi et al. (2018) reported the decrease in solubility and hygroscopicity when working on blanched pumpkin leaf powder (*Telferia occidentalis*). This may be attributed to gelatinization of total carbohydrates and gelation of protein leading to the reducing of the porosity (Agiriga et al., 2015).

5. CONCLUSION

The main drying methods assessed have significantly affected the biochemical and functional properties of the *S. anguivi* powder investigated in this study. The increase in oven-drying temperature resulted in the drop of the moisture. Although decreasing moisture content, oven-drying about 100 °C led to decreasing of powder overall quality. Thus, oven-drying at 80 °C resulted in powders recording optimal biochemical and functional properties with high total polyphenol contents (144.27±0.81 mg GAE/100g DM) and solubility (66.1±1.14 g/100 DM), suggesting their health benefits and their ability to provide stable colloidal solution. In addition, the sun drying, widely used in low-income environment, resulted in a long drying delay promoting degradation of polyphenol compounds.

Blanching process facilitated the drying process and released more total polyphenol contents but decreased the solubility and hygroscopicity of powders. Ultimately, the optimal condition in processing *S. anguivi* into powder was to oven-dry at 80 °C for 24 h without blanching phase. The powder obtained under these conditions might serve as a functional ingredient especially in the diet of people suffering from metabolic diseases as diabetes due to its low carbohydrates content.

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