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The Effect of Steam Blanching and Drying Method on Nutrients, Phytochemicals and Antioxidant Activity of Moringa (*Moringa oleifera* L.) Leaves

Pierre Nobosse[1], Edith N. Fombang[1,*], Carl M F. Mbofung[1,2]

[1]Food Biophysics, Biochemistry and Nutrition Laboratory, Department of Food Science and Nutrition, National School of Agro-Industrial Sciences (ENSAI), University of Ngaoundere, P.O. Box 455, Ngaoundere, Adamawa Region, Cameroon
[2]College of Technology, University of Bamenda, P.O. Box 39, Bambili, North West Region, Cameroon
*Corresponding author: edfombang@yahoo.fr

Abstract The antioxidant activity of plant materials is affected by post-harvest treatments. The present study was undertaken to evaluate the effects of steam blanching and two (solar and electric) drying methods on physicochemical composition, antioxidant activity (AOA) and rehydration properties of *Moringa oleifera* leaves. Fresh and blanched leaves of *M. oleifera* were dried by indirect solar-drying (≈35 ± 3°C, 12 h) and hot air electric drying (50°C, 5 h), and milled into flour (particle size ≤ 500 µm). Fresh, blanched and dried leaves were analyzed for their nutrient and phytochemical contents, antioxidant activity (Total Reducing Power (TRP) and 2,2-diphenyl-2-picryl hydrazyl (DPPH) scavenging activity) as well as rehydration properties (water absorption capacity (WAC) and water solubility index (WSI). Macronutrients content of *M. oleifera* leaves were unaffected by blanching and drying. Irrespective of drying method, drying had a significant negative effect ($p < 0.05$) on phytochemical contents, TRP and DPPH scavenging activity of *M. oleifera* leaves. Blanching prior to drying, however, dimmed the negative effect of the latter. Blanched leaves exhibited higher carotenoids content, TRP and WAC compared to unblanched leaves; whereas blanching caused a decrease in DPPH scavenging activity, vitamin C and WSI. This study highlights that fresh and blanched *Moringa oleifera* leaves are more suiTableas a source of dietary antioxidants than dry leaves.

Keywords: *Moringa oleifera leaves, steam blanching, drying, antioxidant activity, phytochemicals, rehydration properties*

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1. Introduction

An excess of free radicals in the body leads to oxidative stress which plays an important role in the pathogenesis of several human diseases, such as cardiovascular diseases, neurodegenerative diseases, cancer, rheumatoid arthritis, and diabetes [1,2]. Natural antioxidants present in foods protect against these free radicals and are therefore important in maintaining and preserving good health [3,4]. Antioxidant-rich plants are the focus of intense interest since recent reports have expressed safety concerns over the use of synthetic antioxidants [5]. *Moringa oleifera* Lam leaves are considered a significant source of phytochemicals (carotenoids, phenolic compounds, vitamin C) and act as a good source of natural antioxidants [6,7,8]. In developing countries where Moringa leaves are increasingly being used to resolve malnutrition problems, these leaves are either cooked directly after harvesting or are sun or shade dried and stored for future use. The dried leaves are ground and used in the form of powder. Given the increasing interest of populations in this food material, it is necessary to understand the effects of main post-harvest processes on their nutritional properties, phytochemical content and consequently their antioxidant activity. Several reports on post-harvest treatment of *Moringa oleifera* leaves only consider the effect of either blanching or drying alone on macronutrients and vitamins [9,10,11], phenolics content and antioxidant activity [12]. The effect of two boiling methods and four drying techniques on kaempferol and quercetin contents in Moringa leaves has been reported [13]. On the other hand, Saini et al. [14] reported the effects of different drying methods on nutritional, phytochemical and antioxidant activity of Moringa leaves. But in practice at the household-level, blanching is a common preliminary step prior to drying under different conditions. Hence there is a necessity to study the combined effect of blanching and drying on the nutritional and phytochemical contents as well as antioxidant activity of Moringa leaves. The aim of this study was therefore to investigate the effect of steam blanching, followed by two drying methods (solar-drying and electric oven drying) on the nutritional, phytochemical,

antioxidant and rehydration properties of *Moringa oleifera* leaves.

2. Materials and Methods

2.1. Plant Material

Moringa oleifera Leaves were harvested from Maroua, Far North Region of Cameroon and transported overnight in jute bags to the Food Biophysics and Nutritional Biochemistry Laboratory, of the National School of Agro-Industrial Sciences of the University of Ngaoundere. Moringa leaves were sorted, then washed in tab water containing 1% NaCl, rinsed and drained.

2.2. Samples

Fresh leaves (FL): Washed and drained leaves. Stored at 4°C until analyzed.

Blanched leaves (BL): Washed and drained leaves, steam blanched at 95°C for 10 minutes in a steam cooker. The blanching conditions were chosen to ensure a complete inactivation of enzymes responsible for oxidation [15].

Solar-dried leaves (SD): Fresh leaves and blanched leaves dried in a solar drier at about 35 ± 3°C for about 12 hours.

Electric dried Leaves (ED): Fresh leaves and blanched leaves dried in an electric oven at 50°C for 5 hours.

Samples were dried to a final moisture content of 10 % or less. The electric drying was conducted in a forced air convection drier (model CKA-AUF-2000). The indirect solar drying was conducted in an air convection drier. A fan generated air circulation in a 2 m canal made of aluminum and exposed to sun light. Air is then heated, filtered through a dust filter and channeled to the drying chamber placed in the processing room (Figure 1).

The samples were crushed in a porcelain mortar. The dried samples were further sieved through a 500 µm pore sieve (Endecotts, Minor Limited, England). Fresh and blanched leaves were used as control for the drying process. Samples were analyzed for their nutritional composition, phytochemical contents, antioxidant and functional properties.

2.3. Methods of Analyses

2.3.1. Determination of Nutritional Composition

Proximate composition

Portions of fresh, blanched and dry leaves were analyzed separately in triplicate for crude protein, crude fat and ash contents using standard methods of the Association of Official Analytical Chemists [16]. The crude fiber content was measured by the gravimetric method. Total carbohydrates were determined by difference. The moisture content was determined by placing a portion of each sample (M1) in a hot air oven (Memmert, Germany) at 105° C for 24 h. Afterward, the dried sample was again weighed (M2) and the moisture content was calculated as in equation (1).

$$Moisture(\%) = \frac{(M1 - M2)x100}{M1}. \quad (1)$$

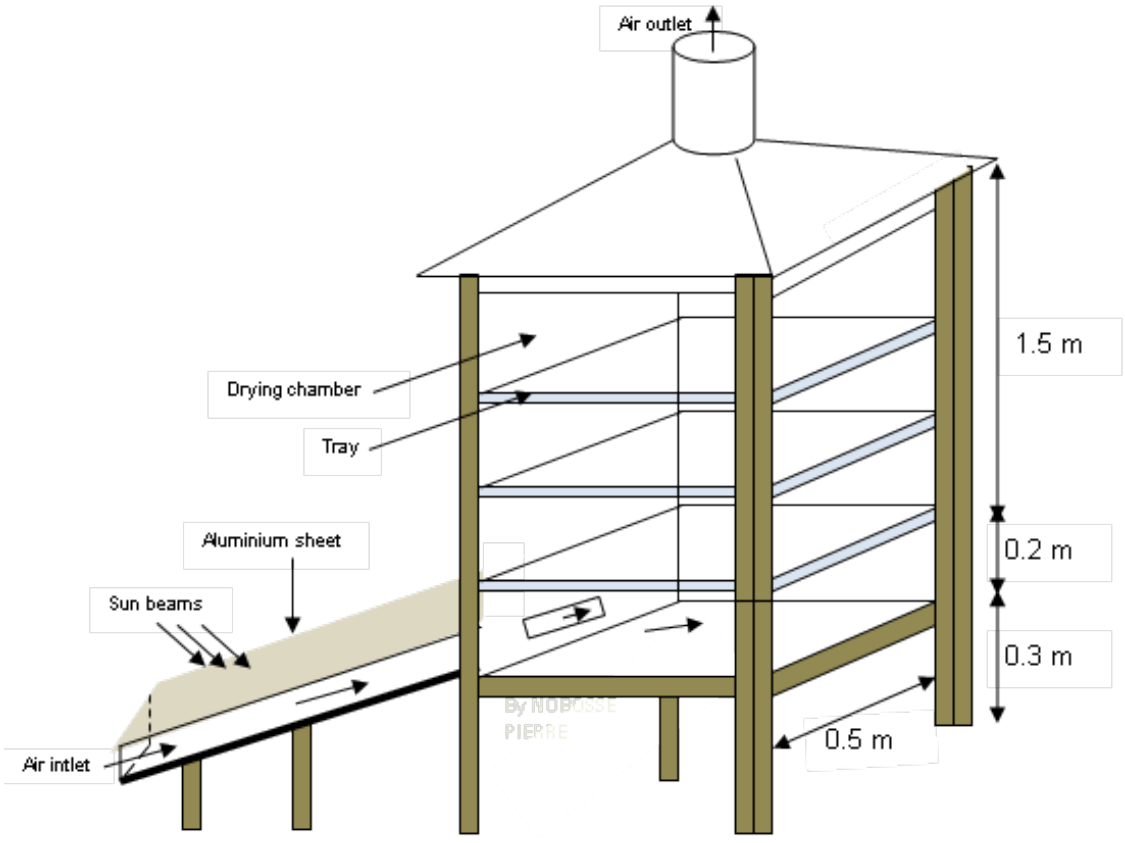

Figure 1. Schematic representation of the solar dryer

Carotenoids

Carotenoids were extracted in a mixture of hexane/acetone (70/30, v/v) under reflux at 60°C [17]. The extract was further washed thrice in a separating funnel in the presence of 1% NaCl aqueous solution. With this, the carotenoids fraction was transferred in hexane and the absorbance measured at 450 nm using a UV-VIS spectrophotometer (Metertech SP8001, Germany). The carotenoids content was calculated as β-carotene equivalent using extinction coefficient of 2592 [18].

Vitamin C (ascorbic acid)

Ascorbic acid was measured according to AOAC method [16]. For extraction of ascorbic acid, 1 g of sample was added to 25 mL of 25% acetic acid and vortexed vigorously. The mixture was centrifuged at 3,500 rpm for 15 min at 0°C (Anke DL-6000B, China). The supernatant was filtered through Whatman N°1 filter paper and diluted to 30mL with 25% acetic acid. Total ascorbic acid content was evaluated by titrimetric assay using 2,6-dichlorophenolindophenol. Results were expressed as mg ascorbic acid per 100 g DM (Dry Matter).

2.3.2. Determination of Phytochemicals Content

Prior to these analyses, samples were first extracted as described below.

Extraction

Sample (1 g) was mixed with 20 mL of 95% ethanol and extracted as described by Makkar *et al* [19] with modifications. The mixture was mechanically shaken for 2 hours (Griffin Flash shaker, London) and centrifuged at 3,700 rpm for 30 minutes at 4° C (Anke DL-6000 B, China). The pellet was re-extracted under the same conditions and both supernatants were pooled and adjusted to 40 mL with 95% ethanol. All extracts were filtered through Whatman N° 1 filter paper and stored at 4°C until analysis.

Total phenolic compounds

Total phenolic compounds in extracts were estimated using the Folin-Ciocalteu's phenol reagent [19]. Briefly, an aliquot (20 µL) of the extracts was mixed with 0.2 mL Folin-Ciocalteu reagent (previously diluted with water 1:16 v/v) and 0.4 mL of 20% sodium carbonate. The tubes were vortexed for 15 s and allowed to stand for 40 min at 40°C for color development. Absorbance was recorded against a reagent blank at 760 nm using a UV-VIS spectrophotometer (Metertech SP8001, Germany). The total phenolic content was expressed as gallic acid equivalents in g/100 g DM.

Flavonoids

Flavonoids were determined according to the method described by Adom *et al* [20]. Aliquots (100 µL) of Moringa extracts were mixed successively with 2.6 mL of deionised water and 0.15 mL of $NaNO_2$ (5%). After incubation at 25°C for 5 minutes; 0.15 mL $AlCl_3$ (10%) was added and the mixture re-incubated under the same conditions. Finally, 1 mL of NaOH 1M was added and the Absorbance was measured at 510 nm (Metertech SP8001, Germany) against a reagent blank. Catechin (0.01%) was used as standard.

Proanthocyanidins content

The proanthocyanidin content was determined by the butanol-HCl method and the proanthocyanidins content (% DM) was calculated as leucocyanidin equivalent assuming the attenuation coefficient of leukocyanidin as 460 [19].

2.3.3. Determination of Antioxidant Propeties

Total Reducing Power

The reducing power of *M. oleifera* extracts was determined by the method using potassium hexacyanoferrate [21] with slight modification. An aliquot of extract (100 µL) was mixed with 0.2 M phosphate buffer (pH 6.6) and 1% $K_4Fe(CN)_6$ and incubated for 20 min at 50°C followed by precipitation with 10% TCA. After centrifugation at 3,500 rpm for 15 minutes, the supernatant was diluted with equal volumes of distilled water and ferric reducing capacities of the extracts were checked by adding 0.1% $FeCl_3$. The absorbance was read at 700nm against a reagent blank. Ascorbic acid was used as reference standard and results expressed as ascorbic acid equivalent (gAAE/100 g DM).

DPPH radical scavenging activity Assay

Radical scavenging activity of extracts of *M. oleifera* was measured by the modified Brand-Williams *et al* [22] method. DPPH in ethanol is a stable radical, dark violet in color. Its color is bleached by its reaction with a hydrogen donor. For analyses, 0.1 mL of each extract was added to 2 mL of 100µM DPPH solution in ethanol. The control was made of 0.1 mL ethanol in 2 mL DPPH. The reaction mixture was incubated for 30 min in the dark at 25°C and the absorbance was read at 517 nm, against a reagent blank. The percentage of free radical scavenging activity was calculated according to equation (2).

$$Scavenging\ activity(\%) = \frac{(\text{Abs. control} - \text{Abs. test})\text{x}100}{Abs\ control} \quad (2)$$

where Abs. is the Absorbance at 517 nm.

2.3.4. Determination of Functional Properties

Water Absorption Capacity and Water Solubility Index

Water absorption capacity was determined as the quantity of water (in grams) absorbed by 100g of powder after saturation and centrifugation [23]. For the determination of these variables, 1 g of powder (MS) was suspended in 10 mL of distilled water, mixed for 30 min (GRIFFIN flash shaker, London) and centrifuged at 3,500 rpm for 30 min. The pellet was weighed (M1) dried at 105°C for 24 h and reweighed (M2). Apparent and real water absorption capacity (aWAC and rWAC) was calculated according to equations (3) and (4) respectively [23] and water solubility index (WSI) was measured as the ratio of dried solids in supernatant to the initial mass according to equation (5) [24].

$$aWAC(\%) = \frac{(M1 - Ms)x100}{Ms} \quad (3)$$

$$rWAC(\%) = \frac{(M1 - M2)x100}{M2} \quad (4)$$

$$WSI(\%) = \frac{(Ms - M2)x100}{Ms}. \quad (5)$$

2.4. Statistical Analysis

All samples were run in triplicates. The data were expressed as mean ± S.D. Data was analysed for variation using one-way analysis of variance (ANOVA) and the means separated by Duncan's multiple-range test and $p<0.05$ was regarded as significant. Graphs were generated using Microsoft office Excel 2013.

3. Results

3.1. Nutritional Composition of *Moringa oleifera* Leaves

Drying reduced moisture content of *Moringa oleifera* leaves from 80% to less than 10 % (Table 1). The leaves can thus be preserved without microbial contamination. Neither blanching nor drying method had any significant effect on the macronutrient composition of *M. oleifera* leaves (Table 1).

The protein content of *Moringa oleifera* leaves and leaf powders ranged between 20 and 22 % on dry basis. The lipids content of *Moringa oleifera* leaves is between 8 and 9.1 %, and they have relatively high fiber content, up to 8% (Table 1). The ash content varied from 8.1 to 10.7 % indicating that *Moringa oleifera* leaves are rich in mineral compounds. Blanching had a significant ($p<0.05$) negative effect on ash content of *Moringa oleifera* leaves with no further effect on drying.

The Vitamin C content of fresh *Moringa oleifera* leaves was 691 mg/ 100 g DM and this was significantly ($p<0.05$) reduced by blanching to 439 mg / 100 g DM (36.5%). Drying of fresh *M. oleifera* leaves on the other hand had a much more destructive effect on its vitamin C content, reducing it to 220 mg/100 g DM (69% reduction) in the electrically dried leaves (Figure 2a).

Blanching prior to drying had a protective effect on the destruction of vitamin C, as blanched dried samples had higher residual vitamin C contents than their unblanched counterparts (Figure 2a). Comparing the drying methods, electrical drying was more protective of vitamin C in blanched leaves whereas solar drying prevented vitamin C loss more in fresh leaves.

Table 1. Macronutrients, ash and fiber content of fresh, blanched and dried M. oleifera leaves (g/100 g DM)

	Fresh Leaves (FL)			Blanched Leaves (BL)		
	FL	FLED	FLSD	BL	BLED	BLSD
Moisture*	79.9±1.0	7.4±0.3	5.5±0.1	77.9±0.5	7.7±0.1	7.9±0.1
Total proteins	20.3±1.0^{a}	21.2±0.4^{a}	21.8±1.9^{a}	22.0±0.6^{a}	21.2±0.1^{a}	21.5±0.1^{a}
Total carbohydrates	53.4±2.3^{a}	53.2±1.6^{a}	51.3±2.1^{a}	53.4±1.7^{a}	54.3±1.0^{a}	53.4±1.5^{a}
Total lipids	8.5±0.5^{a}	8.2±0.8^{a}	9.1±0.5^{a}	8.3±0.8^{a}	8.5±0.4^{a}	8.8±0.5^{a}
Crude fibers	8.3±0.6^{a}	7.8±0.3^{a}	7.1±0.6^{a}	7.7±0.2^{a}	7.7±0.3^{a}	7.8±0.9^{a}
Ash	9.5±0.2^{b}	9.6±0.1^{b}	10.7±0.1^{a}	8.4±0.1^{c}	8.1±0.2^{c}	8.5±0.2^{c}

*: g/100g WB; n=3, Mean ± SD. Values in a row followed by different letters in superscript are significantly different ($p<0.05$). SD: Solar Drying; ED: Electric Drying.

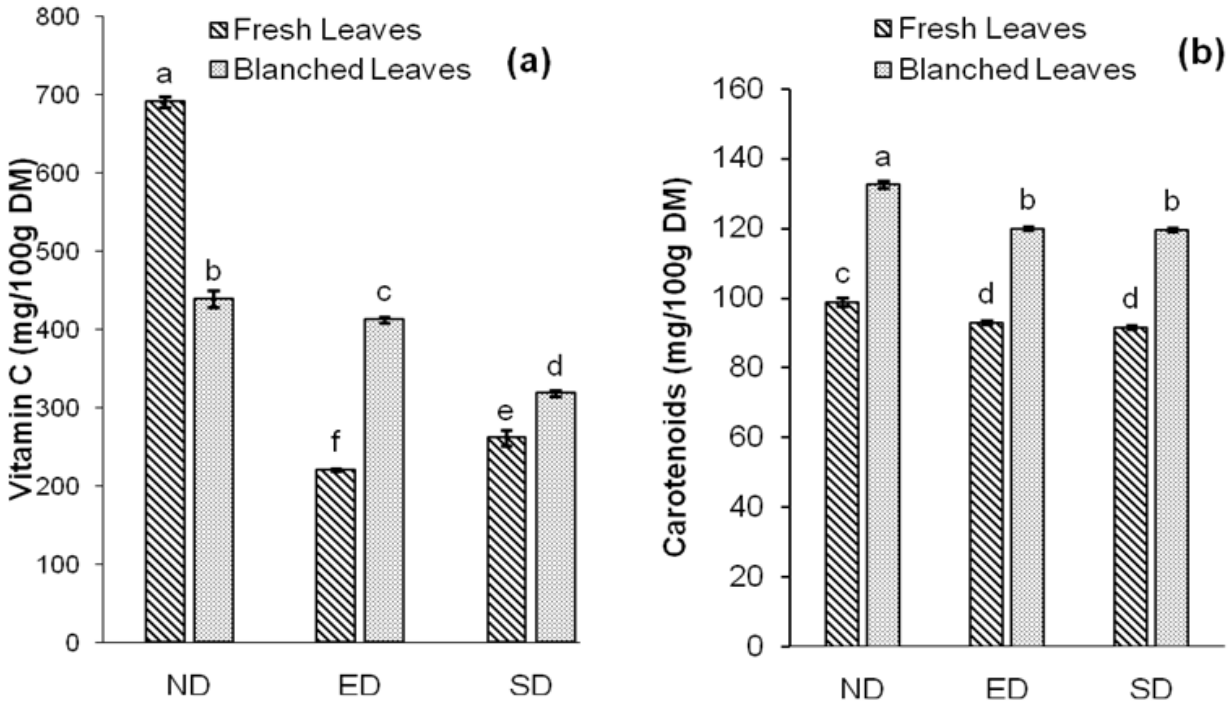

Figure 2. Effect of blanching and drying on vitamin C (a) and carotenoids (b) content of Moringa oleifera leaves. ND: Non Dried; SD: Solar Drying; ED: Electric Drying; Bars with different letters are significantly different ($p<0.05$)

The results of changes in carotenoids content in *Moringa oleifera* leaves with blanching and drying are presented on Figure 2b. The total carotenoids content ranged between 91 in solar dried leaves and 132 mg/ 100 g DM in blanched leaves. Carotenoids content in Moringa leaves was higher in blanched samples compared to fresh samples both before and after drying. Drying had a significant negative effect on carotenoids content (6 to 10 % reduction) in both fresh and blanched leaves. Meanwhile no significant effect of the drying method was observed on carotenoids content.

3.2. Phytochemical and Antioxidant Properties of Moringa Leaves

3.2.1. Phytochemical Content

Table 2 presents phytochemical content of fresh and blanched *Moringa oleifera* leaves as well as powders obtained from the two drying methods.

Total phenolic content ranged between 2.32 and 3.40 % DM while flavonoids ranged between 0.36 and 0.81 % DM. None of the phytochemical components (TPC, flavonoids, PAC) was significantly affected by blanching. Drying affected negatively ($p < 0.05$) phytochemicals in both fresh and blanched leaves. Whereas drying method had no significant ($p > 0.05$) effect on phytochemical contents of fresh leaves, it did for blanched leaves ($p < 0.05$) with total phenolic and flavonoids content decreasing more in solar dried leaves (Table 2).

3.2.2. Antioxidant Activity

Figure 3 presents Total Reducing Power (Figure 3a) and DPPH scavenging activity (Figure 3b) of *Moringa oleifera* leaves with blanching and drying. The maximum reducing power (TRP) is obtained with blanched leaves followed by fresh leaves; whereas fresh leaves exhibited the best DPPH scavenging activity (62.8 ± 2.0 %) compared to blanched leaves (59.1 ± 0.7 %). Drying led to a reduction in the antioxidant activity of leaves, with free radical scavenging activity (30-49.5 % reduction) being more affected than reducing activity (13-23 % reduction) (Figure 3). Solar drying appears more harmful to the DPPH scavenging activity of fresh leaves, but this harmful effect is attenuated when leaves are blanched prior to drying.

Table 3 shows correlation between antioxidant components and antioxidant activity of Moringa leaves. Flavonoids and proanthocyanidins exhibited a significant ($p<0.05$) positive impact ($0.85 < r < 0.92$) on both DPPH scavenging activity and TRP. Vitamin C on the other hand only contributed significantly to DPPH activity ($r = 0.81$). Total polyphenols and carotenoids contribute to a relatively lesser though insignificant extent ($0.34 < r < 0.67$) to antioxidant activity.

Table 2. Phytochemicals content of Moringa oleifera leaves (g/100g DM) with blanching and drying

	Fresh Leaves (FL)			Blanched Leaves (BL)		
	FL	FLED	FLSD	BL	BLED	BLSD
TPC	3.28±0.13^{a}	2.90±0.05^{b}	3.10±0.21^{a,b}	3.40±0.07^{a}	2.67±0.07^{c}	2.32±0.13^{d}
Flavonoids	0.72±0.08^{a}	0.41±0.03^{b}	0.44±0.02^{b}	0.81±0.17^{a}	0.40±0.01^{b}	0.36±0.01^{c}
PAC	0.47±0.04^{a}	0.24±0.01^{b}	0.23±0.01^{b}	0.49±0.03^{a}	0.25±0.02^{b}	0.22±0.01^{b}

n=3; Mean ± SD. Values in a row followed by different letters in superscript are significantly different ($p<0.05$). SD: Solar Drying; ED: Electric Drying; TPC: Total Phenolic Content; PAC: Proanthocyanidins.

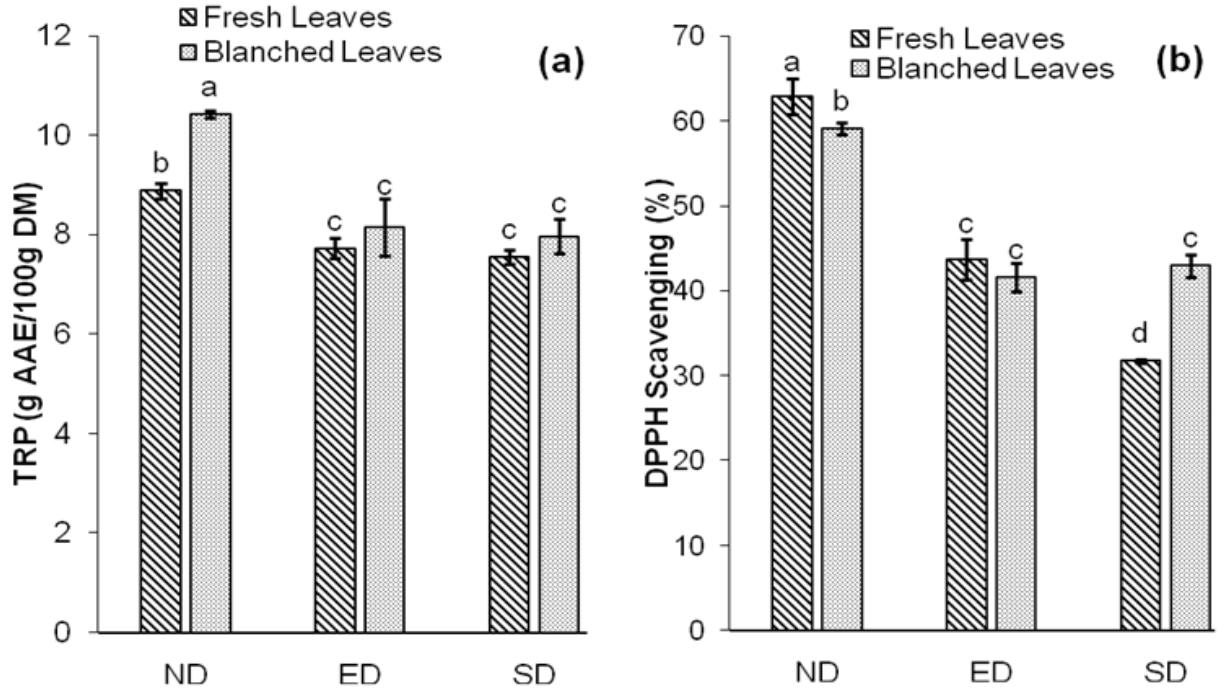

Figure 3. Effect of blanching and drying on Total Reducing Power (a) and DPPH scavenging activity (b) of Moringa oleifera leaves. ND: Non Dried; SD: Solar Drying; ED: Electric Drying; Bars with different letters are significantly different ($p<0.05$)

Table 3. Correlation between antioxidants components and antioxidant activity of Moringa leaves

Variables	TPC	TFC	PAC	Carotenoids	Vitamin C	DPPH	TRP
TPC	**1**						
TFC	**0.843**	**1**					
PAC	0.777	**0.987**	**1**				
Carotenoids	-0.127	0.302	0.323	**1**			
Vitamin C	0.438	0.692	0.782	0.176	**1**		
DPPH	0.535	**0.854**	**0.920**	0.340	**0.810**	**1**	
TRP	0.611	**0.902**	**0.893**	0.668	0.541	0.803	**1**

TPC: Total Phenolic Content; TFC: Total Flavonoids Content; PAC: Proanthocyanidins; TRP: Total reducing power; values in bold are significant ($p<0.05$).

Table 4. Rehydration properties of Moringa oleifera leaf powders

	Fresh leaves (FL)		Blanched leaves (BL)	
	FLED	**FLSD**	**BLED**	**BLSD**
rWAC (gH_2O/100g DM)	495 ± 5^{c}	500 ± 4^{c}	576 ± 4^{a}	560 ± 3^{b}
aWAC (gH_2O/100g DM)	367 ± 5^{b}	363 ± 5^{b}	449 ± 8^{a}	445 ± 2^{a}
WSI (%)	22.3 ± 3.8^{a}	22.5 ± 4.0^{a}	17.0 ± 3.1^{a}	19.0 ± 0.5^{a}

n=3, Mean ± SD. Values in a row followed by different letters in superscript are significantly different ($p<0,05$); SD: Solar Drying; ED: Electric Drying; rWAC: Real Water Absorption Capacity; aWAC: Apparent Water Absorption Capacity; WSI: Water Solubility Index.

3.3. Rehydration Properties of Moringa Leaf Powder

Given that dry *Moringa oleifera* leaves will be further cooked before consumption, their rehydration properties become important. Drying method had no significant effect on WAC and WSI of leaves, with the exception of rWAC of blanched leaves which was significantly ($p<0.05$) higher in the electric dried sample. However, values for WAC were significantly ($p<0.05$) higher in samples blanched prior to drying (Table 4). The values of WAC indicate that Moringa leaf powder is able to hold water up to five times of its mass. WSI was unaffected by either blanching or the drying process.

4. Discussion

M. oleifera leaves contain high levels of proteins (20-22%) and relatively low lipids content (8-9%). According to Amaglo *et al* [25] and Sánchez-Machado [26], these lipids are essentially made up of unsaturated fatty acids such as linolenic acid (51-57%). These observations in addition to its antioxidant activity, reinforces the potentials of *M. oleifera* leaves as ingredient in the formulation of functional foods. The decrease in ash content with blanching could be due to the fact that the heat weakens cell membranes [27] in Moringa tissues and thus, some minerals could have been leached out by condensed steam.

The decrease in vitamin C with blanching and drying is in accordance with the fact that it is a heat labile vitamin easily oxidized on exposure to air and heat [11,28,29] and is also water soluble. In accordance with our observations, Joshi and Metha [10] have equally observed greater vitamin C losses with electric drying of fresh drumstick leaves compared to solar drying while losses of vitamin C with steam blanching have been reported [9,11,30]. In the present study, the carotenoids content of fresh Moringa leaves are in the range of mean values reported by [7,31], and increased with blanching. The increase in carotenoids content of vegetables with hydrothermal treatments such as blanching has been ascribed to the breakdown of the cellulosic structure and to the thermal disruption of the non-covalent associations between carotenoids and proteins, which allows a more effective extraction of carotenoids [27,32]. Similar observations of increased carotenoids content with heat treatments have been reported by Mutiara *et al* [9] in blanched *M. oleifera* leaves and by Ferracane *et al* [27] with cooked Artichoke (*Cynara scolymus*). On the other hand, Pellegrini *et al* [33] found that carotenoids content decreased in cooked Brassica vegetables. It thus appears that the response of carotenoids to hydrothermal treatments may be influenced by the type of treatment. Subsequent drying of both fresh and blanched leaves resulted in a decrease in carotenoids content. Similar observations have been made by Saini et al. [14] after drying of fresh Moringa leaves. Likewise, Gupta *et al* [28] also observed a drop of carotenoids content in blanched Amaranth leaves (*A. tricolor* and *A. gangeticus*) after drying**.** The decrease in both vitamin C and carotenoids content with drying of *Moringa oleifera* leaves could be linked to oxidation and / or the hardening of cell walls during drying leading to low porosity [33] and lower extractability of these components subsequently. The attenuation of this phenomenon in blanched leaf powders could be explained by the fact that some enzymes responsible for oxidative reactions that occur in *M. oleifera* leaves during drying are inactivated by the blanching treatment thereby reducing further oxidative damage during drying.

Antioxidant activity includes prevention of free radical formation, quenching of existing free radicals and reparation of damaged biomolecules. The reduction of

pro-oxidant ions evaluates the ability to prevent free radicals formation while the DPPH assays measures the free radicals scavenging potential. The antioxidant activity of *M. oleifera* leaves and leaf powders (Figure 3) indicated their capacity to prevent tissues oxidation by sequestration of free electrons and quenching of free radicals present in biological media. Flavonoids and proanthocyanidins emerged as main antioxidants involved in both radical scavenging and ion reduction. Vitamin C appears mainly involved in free radicals scavenging activity while carotenoids and total phenols are mostly implicated but to a lessr extend in the ion reducing power (Table 3). Phenolic compounds in general and flavonoids in particular are endowed with antioxidant activity, and play a fundamental role in scavenging free radicals and in the prevention of lipids peroxidation [34]. In general the effects of hydrothermal treatments on antioxidant activity vary according to plant material, treatment conditions and the assay used for measurement [30]. TRP in this study increased with blanching (15 %) whereas DPPH decreased by 6 %. Enhancement of antioxidant activity has been reported in several leafy vegetables after steaming compared to raw sample [27,30]. On the other hand, Yakubu *et al* [35] reported a significant decrease in the reducing power and the DPPH scavenging activity of blanched bitter leaves (*Vernonia amygdalina*) with respect to fresh leaves. Drying, in this study, reduced AOA in both fresh and blanched samples, with the lowest antioxidant activity recorded in fresh solar dried leaves. This reduction is in accordance with the observation of Wangcharoen and Gomolmanee [36] who recorded a 40% reduction in AOA of hot air dried *M. oleifera* leaves. The variations in AOA could be explained by the fact that heat treatments can either degrade or enhance the extractability (through matrix softening) of phytochemicals involved with AOA [30]. Alternatively, heat treatments could cause structural modifications and/or polymerization of phytochemicals, leading to new-formed compounds with different AOA with respect to their parent compounds [27].

The presence of vitamins and phenolic compounds in *Moringa oleifera* is important as it not only improves its nutritional value, but their antioxidant role is an additional asset helping in the fight against ageing and many chronic diseases such as cancers, diabetes and cardio-vascular diseases [3,4,37]. Therefore, based on the results of this study, the consumption of either fresh or blanched *Moringa oleifera* leaves could be beneficial in the prevention of chronic diseases. In addition, their relatively high fiber content, up to 8% (Table 1), could confer on them prebiotic properties with several health benefits [38].

In food materials the WSI is complementary to the WAC. WSI provides an indication of which portion of material can get solubilized in water upon soaking while WAC indicates the capacity of material to absorb water. The observation that Moringa leaf powder is able to hold water up to five times its mass (Table 4), is very appreciable since solid-water interactions constitute a limiting factor in the utilization of food powders [39]. Also, the water absorption capacity of food powders is positively correlated to proteins, starch and pentosans [40]. Thus the higher values of WAC in blanched M. oleifera leaf powder indicate that proteins and sugars were made more available by the blanching process.

5. Conclusion

The present study shows that macronutrients content of *M. oleifera* leaves are not significantly affected by blanching and/or drying treatments. The total carotenoids content of *M. oleifera* leaves is improved by steam blanching but is negatively affected by drying. The negative impact of drying on vitamin C content of *M. oleifera* leaves is limited when they are steamed prior to drying. Steam blanching improves total reducing power but not DPPH scavenging activity in *M. oleifera* leaves. Overall, steam blanching is favorable to most phytochemicals and ion reducing capacity of Moringa leaves but steaming prior to drying is not better than direct drying. This study highlights the fact that fresh and steam blanched *Moringa oleifera* leaves are more suitable as a source of dietary antioxidants than dried leaves. Steam blanching prior to drying appears to be an appropriate process for preservation of components like ascorbic acid and carotenoids. Solar drying is more harmful to the scavenging capacity in unblanched *M. oleifera* leaves. Blanching prior to drying improve the water absorption capacity of *M. oleifera* leaf powders.

Conflict of Interest

Authors declare no conflict of interest.

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