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Effect of Different Processing Methods on Total Phenolic and Total Flavonoid Content of Selected Indigenous Vegetables

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Abstract: Foods rich in phytochemicals are well recognized for their role in the prevention of chronic disease development, in addition to fulfilling the nutrient requirements. However, different processing methods employed during preparation may affect their levels and functionality as they are sensitive to different processing parameters such as temperature and light. This study aimed to evaluate the effects of three common processing methods; boiling, fermentation, and drying (sun and solar drying, with and without blanching), on total phenolic content and total flavonoid content in cassava (*Manhot esculenta Crantz*), black jack (*Bidens pilosa*) and bitter lettuce leaves (*Launaea cornuta*) grown in Mkuranga District in the Eastern part of Tanzania. Total phenolic content and total flavonoid content were analyzed by using the spectrophotometric method with the use of Folin-Ciocalteu and Aluminum Chloride reagents, respectively. Total phenolic content ranged from 0.9 ± 0.14 to 85.7 ± 0.56 mg Gallic Acid Equivalent (GAE)/100g and flavonoids ranged from 0.03 ± 0.00 to 3.9 ± 0.03 mg/100g across the treatments. Both parameters were adversely affected by fermentation and boiling, while solar and sun drying only reduced the flavonoid content. Results showed that direct solar and sun drying appear to be effective processing methods, for the retention and maintenance of total phenolic content in all samples while, none proved to be effective for flavonoid content.

Keywords: Indigenous Vegetables, Total Phenolic Content, Total Flavonoid Content, Boiling, Fermentation, Solar Drying, Sun Drying

1. Introduction

Phytochemicals are vital components of plants with antioxidant activities. Plants release these secondary metabolites in reaction to various stress factors. They protect plants from UV radiation, control oxidative stress, and shield plants from microbes [1, 2]. Indigenous vegetables are a good source of the aforementioned chemicals because they contain significant amounts of phenolic and flavonoid components. Native vegetables are known to have high levels of antioxidants, which offer powerful protective effects against various diseases linked to oxidative damage [3, 4].

Due to their numerous health advantages, eating foods strong in antioxidant activity, especially indigenous vegetables, has recently drawn a lot of attention. Foods with strong antioxidant activity have been linked to a decreased risk of degenerative diseases and cancer because they can reduce lipid oxidation, DNA deterioration, and prevent malignant transformation [5, 6]. Particularly, flavonoid and phenolic compounds have

garnered a lot of interest as possible therapeutic agents for malignant transformation and ROS-targeted cancer prevention [7]. Therefore, in addition to their high nutritional profile, indigenous vegetables have the potential to avert the emergency of cancer and degenerative diseases.

The extreme perishability of native vegetables, however, may limit their availability and consumption, jeopardizing the phytochemicals' ability to be exploited. Indigenous vegetables start to lose their quality as soon as they are plucked and have a short shelf life [8]. According to [9], approximately 50% of some vegetables are lost due to post-harvest treatments. The high perishability of vegetables, inadequate processing and physical damage lead to the loss of their wholesomeness. This also contributes to the loss of nutrients as well. For instance, in the supply chain of African nightshade in Kenya, the loss of micronutrients and protein content was reported to be in the range of 3.2% to 29.4%, while the loss of chlorophyll and carotenoid range between 70.9% to 90.9% and 70.4% to 91.9% respectively [10]. This suggests that in addition to financial losses, inadequate post-harvest handling and lack of proper processing can decrease the nutritional value of indigenous vegetables.

Proper processing of indigenous vegetables is necessary to preserve important minerals and phytochemicals and extend their shelf life [11]. However, the act of processing vegetables results in the reduction of nutrients such as vitamins, minerals and bioactive compounds such as phenolic compounds and flavonoid compounds [12]. Many vegetables are frequently processed before being consumed, and when they are made at home, they are typically treated without considering nutrients and other bioactive compounds such as phytochemicals, based on local convenience, culinary customs and taste preferences.

The effect of different processing methods has been studied extensively in recent years in some vegetables and it is highly dependent on the type of vegetables, the type of processing methods and the processing conditions [13, 14, 15]. These methods may lead to leaching, degradation and transformation of these substances, which would lower their concentration [14]. Understanding the effect of these processing methods on the total phenolic content and flavonoid content is crucial for optimizing the nutritional value of vegetables.

Considering these, this study determined the effect of boiling, fermentation, solar and sun drying (with and without blanching) on total phenolic content and flavonoid content in black jack, bitter lettuce and cassava leaves widely grown in the Mkuranga District found in the coastal region in the Eastern part of Tanzania.

2. Materials and Methods

2.1. Description of the study area

This study was conducted in Mkuranga District, which is located in the Pwani Region in the Eastern part of Tanzania (Figure 1). Mkuranga District has a total surface area of 2,827 of which 1985 km2 is on the mainland and 447 km2 is covered by the Mafia channel. It is located at latitude 7.1219° South and longitude 39.2° East. It is bordered to the North by Dar es Salaam's Kigamboni, Temeke and Ilala Districts. To the East, it is flanked by the Mafia Channel, to the South by Kibiti District and to the West by Kisarawe District. The area of the mainland that is covered by forest reserves is 52 km2. The District includes 1934 km2 of land which is useful for cultivation, while 1662.3 km2 of the land is under cultivation. Administratively, it is subdivided into 25 Wards and among those, two (Mkamba and Kisegese) were purposely selected for sample collection.
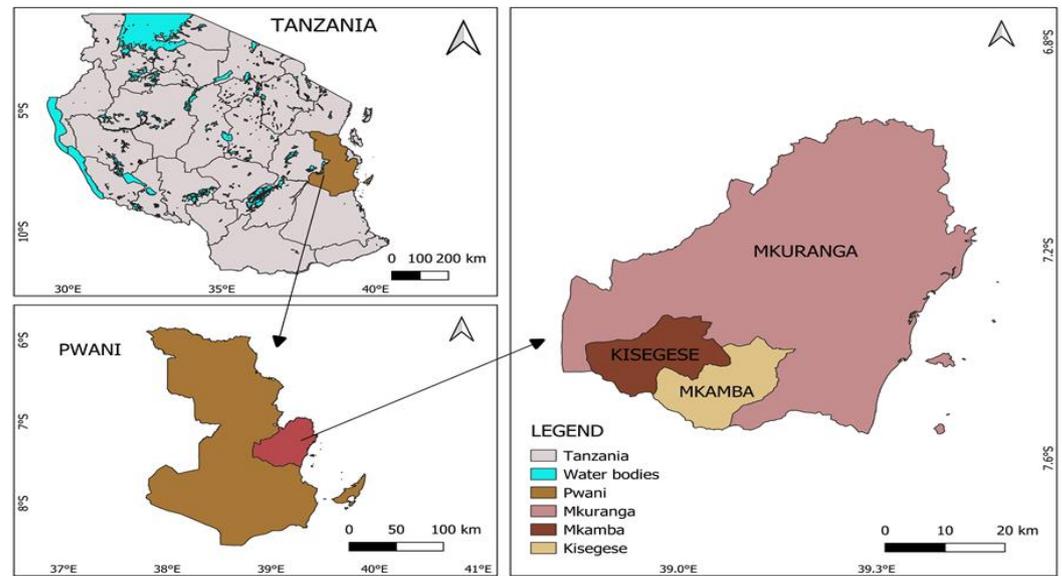
Figure 1. Map of Mkuranga District showing the study area, (Source; Compiled from Wikipedia)

2.2. Sample collection

Three indigenous vegetables (black jack leaves, cassava leaves and bitter lettuce leaves) that are commonly consumed in Mkuranga District were used in this study. Vegetable samples were purposively selected due to their availability and accessibility during the study period. A total of 4 kg of each vegetable sample was collected from two production areas in each ward (Mkamba and Kisegese) with the help of the natives. Vegetable samples were harvested, cleaned to remove dust and put in sealed plastic bags. The samples were then placed in a cool box and transported to the laboratory at Sokoine University of Agriculture, where they were stored at 4°C for one day before further processing and laboratory analysis. Figure 2 shows the pictures of the vegetables after collecting the edible portions.

(a)   (b)   (c)

Figure 2. Pictures of the three vegetables taken from the selected farms (A: Bitter lettuce, B: Cassava leaves, C: Black jack)

2.3. Sample preparation and treatment

Before processing, vegetable samples were sorted, washed with distilled water and left to drain water. The edible portions of vegetables were subjected to boiling,

fermentation, solar and sun drying (with and without blanching). The processing methods were carried out as follows:

2.3.1. Boiling

Five hundred grams (500 g) of the edible portions of each vegetable were cut in 4-8 mm pieces and put in one liter (1L) of distilled water and were boiled separately to 100ºC for 15 minutes before the analysis of total phenolic content and flavonoid content [17, 18].

2.3.2. Fermentation

The fermentation process was carried out according to [19], with some modifications. Five hundred (500) g of raw vegetables were shredded into 2 cm thick pieces and placed into jars. The jars with the vegetables were filled with 15% salt (NaCl). The salt content was able was enough to cover the sliced vegetables. The jars were then covered with screw caps and kept at room temperature for 14 days. The vegetables were subjected to pH measurement after every one week. The fermented vegetables were analyzed for total phenolic content and flavonoid content.

2.3.3. Sun drying and solar drying of vegetables

Approximately 1 kg of each vegetable sample was divided into two equal portions and one portion was subjected to blanching at 95℃ for 5 minutes and immediately cooled under running distilled water to avoid further cooking and the other portion was left without blanching. The blanched and non-blanched portions of each vegetable were left to dry under the sun for two consecutive days before analyzing the total phenolic content and flavonoid content, after measuring the moisture content. The same procedures were conducted for solar-dried samples, where the two portions were subjected to walk-in/greenhouse-solar driers of which for 5-7 hours in a single day. In both cases, the samples were constantly turned to avert fungal growth [20, 21]. Figure 3 shows the vegetables undergoing drying using the two methods.
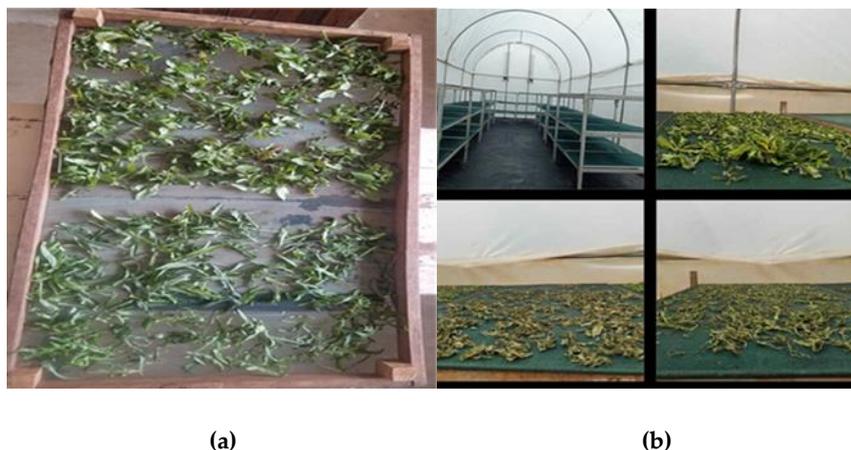

(a)   (b)

Figure 3. Pictures (a) and (B) show sun drying and solar drying of vegetables respectively

2.4. Determination of Total phenolic content

The Folin-Ciocalteu technique was used to determine the extracts' total phenolic content with a few minor changes. 0.5 ml of Folin-Ciocalteu reagent was combined with two (2) ml of extracts, and the mixture was incubated for 5 minutes at room temperature. After adding 1.5 milliliters of 7.5% sodium carbonate solution, the reaction was allowed to sit at room temperature for one and a half hours while kept in the dark. The samples were then measured at 725 nm using a UV-visible spectrophotometer (Double beam UV-3000 model X-ma3000 spectrophotometer Human Corporation, England) with the

absorbances of the samples measured against the reagent as a blank. Gallic acid was used as a standard and the concentration range of 20 – 500 µg Gallic Acid/ml was used to prepare a calibration curve. The milligram of Gallic Acid equivalents per gram of extract (mg GAE/100g extract) was used to express the total phenolic content. The test sample was substituted with 100 µl of dimethyl sulfoxide (DMSO) to prepare the negative control [22].

2.5. Determination of Total flavonoid content

The Aluminium Chloride colorimetric method was used, with minor adjustments, to determine the total flavonoid concentration of the extracts. Briefly, 0.5 ml of the extracts were mixed with 5 ml of 10% aluminium chloride solution, and then 5 ml of potassium acetate (1M) was added with 3 ml of distilled water. The reaction mixture was then allowed to sit at room temperature for half an hour. The absorbance of the tested samples was measured at 519 nm against the reagent as blank, using a UV-visible spectrophotometer (Double beam UV-3000 model X-ma3000 spectrophotometer Human Corporation, England). Plotting the calibration curve was done using a standard of 20-500 µg/ml of catechin and the amount of flavonoid content was expressed as milligrams of Catechin equivalent per 100 grams of extract (mg CE/100g extract). While, 100µl of dimethyl sulfoxide instead of the extract was used to prepare the negative control [22].

2.6. Data analysis

All data on total phenolic content and flavonoid content were analyzed by using the Statistical Package for Social Sciences (SPSS) statistical software version 25. A one-way analysis of variance (ANOVA) test was performed followed by a post hoc test, Turkey (HSD) with significance differences being determined at a 5% level of significance ($P<0.05$). All results were expressed as mean ± standard variation of triplicate values.

3. Results and Discussion

The results of total phenolic content and total flavonoid content of the leaves of cassava, bitter lettuce and black jack before and after being subjected to boiling, fermentation, solar drying (with and without blanching) and sun drying (with and without blanching) are presented in Table 1.

Table 1. Phytochemical composition (mg/100g) of raw and processed black jack, bitter lettuce and cassava leaves

Vegetables	Processing methods	Total phenolic content(mgGAE/100g)	Total flavonoid content(mg CE/100g)
	Raw	22.7±1.09[c]	3.0±0.07[c]
	Boiling	1.7±0.26[a]	0.2±0.04[a]
	Fermentation	27.9±2.53[c]	0.6±0.14[b]
Cassava leaves	Blanching-solar drying	15.2±3.11[bc]	0.4±0.46[ab]
	Blanching-sun drying	11.3 ±0.68[b]	0.6±0.07[b]
	Direct solar drying	67.6±3.04[d]	0.3±0.02[a]
	Direct sun drying	85.7 ± 0.56[e]	0.4±0.03[ab]
	Raw	16.2 ± 0.44[b]	3.4±0.06[d]
	Boiling	1.8±0.28[a]	0.03±0.00[a]
	Fermentation	4.1±0.01[a]	0.3±0.07[b]
Bitter lettuce	Blanching-solar drying	10.9 ± 0.44[ab]	0.3±0.01[b]
	Blanching-sun drying	8.48 ± 2.74[ab]	0.4±0.07[bc]
	Direct solar drying	36.3 ± 3.74[c]	0.5±0.03[c]
	Direct sun drying	41.1 ± 4.09[c]	0.5±0.04[c]

	Raw	19.9±1.13[b]	3.9±0.03[d]
	Boiling	0.9±0.14[a]	0.2±0.02[a]
	Fermentation	5.8±0.78[ab]	0.3±0.03[ab]
Blackjack	Blanching-solar drying	7.6 ± 0.75[ab]	0.5±0.11[b]
	Blanching-sun drying	11.4 ± 1.48[ab]	0.7±0.00[c]
	Direct solar drying	68.4 ± 9.67[c]	0.8±0.04[c]
	Direct sun drying	70.9 ± 3.87[c]	0.7±0.04[c]

Values are expressed as mean ± standard deviation (n = 3). Mean values with different superscript letters along the columns are significantly different at ($P<0.05$).

3.1. Effect of different processing methods on Total phenolic content

The results of total phenolic content ranged from 1.7±0.26 to 85.7 ± 0.56mg GAE/100g in cassava leaves, 4.1±0.01 to 41.1 ± 4.09 mg GAE/100g in bitter lettuce and 0.9±0.14 to 70.9 ± 3.87 mg GAE/100g in black jack. The highest TPC content (mg GAE/100g) was observed in cassava leaves at 22.7±1.09, followed by black jack 19.9 ± 1.13 and bitter lettuce at 16.2 ± 0.44. In cassava leaves, there was a significant reduction in TPC in boiled and blanched-sun-dried samples, while fermentation and blanching-solar drying had no significant effect on TPC cassava leaves. There was a significant increase in TPC in direct solar and sun-dried samples. There was a significant difference between drying operations that were pretreated with blanching and those that were not pretreated with blanching. Unblanched samples had higher TPC than blanched samples.

In bitter lettuce, there was a significant reduction in TPC in boiled and fermented samples. Direct solar and sun drying led to a significant increase in TPC while there was a non-significant difference between raw and dried samples that were treated with blanching. In black jack, there was a significant reduction in TPC in boiled samples while fermentation, blanched solar and sun-dried samples resulted in non-significant differences in TPC. A notable increase in TPC was observed in all solar and direct sun-dried samples. The trend in TPC in different processing methods varies across the vegetables and this could be attributed to the difference in vegetable samples and their morphological structure.

The levels of TPC in raw cassava were high compared to the results (64 mg GAE/100g) reported by [23] and it was low compared to the results (748000 mg GAE/100g) reported by [24]. Most of the reported results on TPC in black jack were inconsistent with the findings of this study. [25] reported a higher content of TPC (179.3 mg GAE/g) in black jack compared to the content in this study, also the results reported by [26] were significantly higher than those observed in the present study. On the other hand, the TPC in raw bitter lettuce was significantly low compared to the results reported by [27]. The varied levels in TPC among investigations could be attributed to differences in extraction methods, plant varieties, soils and sampling locations.

The boiling operations significantly reduced ($P<0.05$) the TPC in all vegetable samples. Boiled samples were shown to have the lowest TPC value of all processing techniques. The outcome was in line with research conducted by [28] on broccoli, which showed that boiling broccoli for 15 minutes reduced phenolic content concentration by about 50%. Similarly, [29] reported on *Hericium erinaceum* and suggested that temperature and water as a cooking medium are the determining factors that influence the total phenolic content. [30], also reported a significant decrease in TPC in black jack after boiling operations. Studies have also reported that boiling leads to polyphenol losses due to leaching into boiling water [31]. According to [32], the ability of phenolic compounds to form hydrogen-bonded clusters with water is highly enhanced by the presence of hydroxyl group (-OH), this causes the leaching of phenolic compounds into the

surrounding water. This harms the total phenolic content, hence, the consumption of the water used in the processing operations may compensate the leached TPC.

The present study found that fermentation significantly decreased TPC in bitter lettuce only, the effect was not significant in black jack and cassava leaves. The inconsistency could be attributed to the differences in vegetable samples, time of fermentation the vegetables were subjected to and the fermentation conditions such as temperature and the concentration of salt. The present findings contradict some of the previous studies which reported a significant increase in total phenolic content after fermentation. In particular, [33] reported a significant rise in TPC in cassava leaves after fermentation. Another study evaluated the influence of fermentation on TPC and found a significant increase in TPC in plant-based foods [34]. Their findings were correlated to the microbial activity that breaks down the matrix cell wall, thus encouraging the release of bound phenolic compounds and increasing their availability [34]. Fermentation involves the action of microorganisms like bacteria which produce enzymes that break down larger molecules including phenolic compounds into smaller forms, as a result, phenolic compounds that were initially bound in complex structures become more accessible after fermentation [35]. The specific changes in phenolic content after fermentation depend on the type of vegetable being fermented, conditions and microorganisms involved during fermentation. Fermentation of leafy vegetables has been reported to have potential benefits such as improving safety, prolonging shelf life and enhancing the availability of some nutrients. Fermentation can also increase the bioavailability of minerals and vitamins, production of antimicrobial and antioxidant compounds and stimulate probiotic functions [36]. These results show that the effect of fermentation on TPC varies with the type of vegetable samples.

The present study found a significant increase in TPC concentration in solar and sun-dried samples. This is observed because the drying techniques expedite the degradation of bound phenolic compounds during the cellular component breakdown process [37]. Also, exposure of vegetables to solar or sun drying leads to the evaporation of water from the vegetables thus contributing to the concentration of phenolic compounds and hence the corresponding observed increase in TPC concentration in the dried samples than in their fresh counterparts [38]. The present findings are similar to the results reported by [39], who did a study on apples and found that TPC increased after solar drying treatment without pre-treatment blanching. Also, it was in line with the study that evaluated the effect of sun drying on cassava leaves and found that sun drying without pre-treatment blanching retains 62% of the polyphenol content [40]. Even though both sun and solar drying contributed to an increase in TPC concentration, solar drying is an effective method of drying because it involves drying food products in an enclosed space which is more controlled, hence controlling contamination and loss of nutrients than sun drying [41].

Furthermore, the present study found that TPC concentration decreased in blanched-sun dries and solar-dried samples. The reduction in TPC could be due to the combined effect of blanching and drying processes. Blanching involves the exposure of vegetables to high temperatures which leads to the degradation of polyphenols [42]. The initial loss of phenolic compounds during blanching is exacerbated during the process of drying, resulting in a reduction in the TPC of the vegetables [43]. Additionally, the reduction of TPC during drying could be attributed to oxidative enzymes and the result of changes in the structure of phenolic compounds [44]. These results were inconsistent with the study conducted on capsicum and carrots by [45] and [46]. However, they were similar to the results reported by [47]. The specific impact of blanching on TPC may vary depending on the type of vegetable, duration and temperature of blanching [42]. In this case, TPC decreased significantly after the combination of blanching and drying. As far as the retention of TPC is of greater concern, these results show that the combination of blanching and drying has proven ineffective.

3.2. Effect of different processing methods on Total Flavonoid content (TFC)

The results of flavonoid content ranged from 3.0 ± 0.07 to 0.2 ± 0.04 mg CE/100g in cassava leaves, 3.4 ± 0.06 to 0.03 ± 0.00 mg CE/100g in bitter lettuce and from 3.9 ± 0.03 to 0.2 ± 0.02 mg CE/100g in black jack. Black jack had the highest total flavonoid content, followed by bitter lettuce and black jack. In cassava leaves, there was a significant reduction in flavonoid content in all processing methods. The lowest flavonoid content was observed in boiled samples. There was a non-significant difference in flavonoid content between dried samples that were pretreated with blanching and those that were not pretreated with blanching. The flavonoid levels in cassava leaves were observed in the following trend: Raw > fermentation > blanching-sun drying > blanching- solar drying > direct sun drying > direct solar drying > boiling.

In bitter lettuce, there was a significant decrease (P<0.05) in flavonoid content in all processing methods. The lowest flavonoid content was in boiled samples. There was a significant difference (P<0.05) in flavonoid content between blanching-solar drying and direct solar drying while no significant changes were observed in sun drying treatments. The flavonoid content in bitter lettuce was observed in the following trend: Raw > direct sun drying > direct solar drying > blanching-sun drying >fermentation > blanching- solar drying > boiling.

In black jack, there was a significant reduction of flavonoid content in all processing operations. The lowest flavonoid content was in boiled samples. There was a significant difference in flavonoid content between blanching-solar drying and direct solar drying while no significant changes were observed in sun drying treatments. The flavonoid content in bitter lettuce was observed in the following trend: Raw > direct solar drying> direct sun drying > blanching-sun drying> blanching- solar drying > fermentation > boiling. The trend of flavonoid content in different processing methods varied among the three vegetables. This observation could be attributed to the difference in vegetable types and the difference in their morphological structures.

Flavonoids are plant components that have been associated with several biological activities such as antioxidant, anti-inflammatory and anti-carcinogenic activities [48]. The content of flavonoids in raw cassava leaves was a hundred times lower compared to the levels reported by [49] and [50]. The content of flavonoid in bitter lettuce was also low compared to the one reported by [51] and [27]. The flavonoid content in black jack was low compared to the one reported by [52]. The variations in total flavonoid content among the investigations could be attributed to the extraction method, plant varieties and/or sampling locations.

This study reports a significant reduction in flavonoid content in solar and sun-dried samples. This is evidenced by some of the previous studies that reported a substantial decrease in flavonoid levels after drying. The decrease in flavonoid levels is likely due to oxidative and thermal degradation during the process [53, 54, 55]. [55] reported that sun drying results in a greater loss of flavonoid content than oven drying and associated this with temperature and exposure to sunlight, which promote the degradation of flavonoids. Additionally, there was a significant decrease in flavonoid levels in samples that were blanched before sun and solar drying. This could be attributed to the leaching of flavonoids in water during blanching followed by solar drying [56]. According to [57], blanching affects the chemical compounds especially flavonoids which are likely to be leached into the water. This observation is similar to the results reported by [58] who found a decrease in the flavonoid levels of moringa leaves in solar-dried samples of vegetables with hydrothermal treatment such as blanching.

Contrary to the present findings, an increase in flavonoid content after drying (with blanching, direct sun drying and direct solar drying) has been reported previously [59]. Their results were attributed to the concentration effect due to water removal. Flavonoids are water-soluble compounds and as the water content is reduced during the drying

process, the relative concentration of flavonoids in the remaining material increases. Also, [60] reported an increase in flavonoid levels. They suggested that drying influences the liberation of flavonoids in vegetables due to microstructural changes which cause negative, neutral and positive changes in total flavonoid content. The present results depict that solar and sun drying are not recommended if the goal is to maximize flavonoid retention.

Moreover, a significant reduction in flavonoid levels was observed in boiled vegetables. This could be due to the leaching of flavonoids in water due to their sensitivity to heat [61]. Similar results on the reduction of flavonoids after boiling have been reported [62]. The reduction was associated with flavonoid degradation as a result of the dispersion of flavonoids into the cooking water and the oxidation of flavonoids at higher temperatures. Several studies have reported similar results on flavonoid content in boiled vegetables. A study on cassava leaves reported a significant reduction of flavonoid content after boiling [63]. Also, a study on the influence of boiling on phenolic compounds and the bioactivity of black jack revealed that the flavonoid content decreases after boiling [30]. Moreover, a study on the effect of different cooking methods on the nutritional quality of vegetables found that boiling has more adverse effects on flavonoid levels in most vegetables [64]. Contrary to these results, some studies have shown that boiling can lead to an increase in flavonoids due to the breakdown of the cellular matrix making flavonoids extractable into solvents [65]. For instance, a study by [66] and a study done by [65] reported that the boiled samples have higher flavonoid content than their raw forms. The influence of boiling on flavonoid content in vegetables varies depending on the type of vegetables, time used for boiling and the methods used for the extraction of flavonoids.

Concerning fermentation, the present findings show that all fermented vegetable samples had lower flavonoid content than their corresponding raw samples. The reduction of flavonoids after fermentation could be attributed to the longer fermentation period and the sample concentration of flavonoid compounds. Similar effects were reported by [67] who observed the reduction in flavonoid levels after the fermentation of pistachio hulls and suggested that the decrease in flavonoid levels could be associated with the fermentation period and the sample concentration of flavonoid compounds. Also, the present results are in line with [68] that total flavonoid content decreases during fermentation and after storage in brine due to the transfer of flavonoids from the green table olives to the fermentation solution. This is inconsistent with the observation reported by [69] who reported a significant increase in flavonoid levels after the fermentation of moringa seeds. Also, [70] reported increased total flavonoid levels in different vegetables after fermentation. A notable increase in total flavonoid content could be attributed to the microorganisms' ability to release bound flavonoid compounds and increase their availability for extraction [71]. The type of vegetable, fermentation conditions, extraction method and the salt concentration media, tend to influence the effect of fermentation on a certain vegetable sample. Since the flavonoid content is leached into the fermentation solution, consuming the fermented vegetables with the solution is advisable.

4. Conclusion

Based on the findings of this study, it is evident that fermentation significantly reduced total phenolic content in bitter lettuce and black jack, and flavonoid content in all three vegetable samples. Also, boiling significantly reduced total phenolic and flavonoid content in all selected vegetable samples. The decrease highlights the susceptibility of phenolic compounds to thermal and enzymatic degradation during processing. On the other hand, pretreating samples with blanching before drying has proven ineffective in some samples and has no effect at all in other samples. Ineffectiveness in the combination of blanching and drying could be associated to the cooling in running water and instead, cooling in ice is recommended. Solar and sun drying proved to be efficient in retaining the total phenolic content only. Therefore, if the goal is to maintain flavonoid and total

phenolic content, boiling for 15 minutes and fermentation for 24 days are not recommended, unless the water is preserved after the process. Furthermore, reducing degradation of phytochemicals for possible health benefits requires optimizing food processing parameters.

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