EFFECT OF HARVESTING STAGE AND DRYING METHOD ON COWPEA LEAF NUTRIENT COMPOSITION

ABSTRACT

Cowpea leaves are lost annually due to infestation and spoilage when being transported to clients and the losses at the local markets are brought on by inadequate postharvest handling procedures and market glut, particularly during peak seasons. High moisture content from the cowpea leaves at harvest stage may contribute to increased spoilage hence lowering quantity and quality. The choice of appropriate harvesting stage and drying method can help to reduce this problem. The aim of this study was to determine the best harvesting stage and efficient drying method that would maintain high leaf nutrient composition. Cowpeas variety M66 was used for the research and the treatments included three harvesting stages (21, 35 and 49 days after sowing [DAS]), three drying methods (open sun, solar dryer and oven. Data was collected on iron, calcium, crude fibre, beta carotene, protein and moisture content. The data was subjected for variance using Statistical Analysis System 9.2 edition and significantly different means separated using least significant difference at 5%. The results indicated significant ($p<0.05$) differences in moisture, calcium, proteins, beta carotene and crude fibre content in both trials. Harvest stage and drying method did not significantly ($p<0.05$) influence the iron content. Oven and solar drying methods showed better nutrient and mineral retention in the three harvesting stages when compared to the open sun drying method.

Key words: Cowpea; Leaves; Harvesting stage; Drying method; Nutrient content,

1. INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp) is a warm-season, annual crop from Fabaceae or Leguminosae family with a wide range of uses. It is an important pulse crop that can be adopted for food security and population health around the globe with major nutritional benefits. The leaves provide nutrients including beta-carotene, iron, calcium, zinc, fiber, phytonutrients, and protein, all of which are present in small portions [1, 2]. Seasonality in production has been reported to be the major challenge in promoting utilizations of cowpea leaves as most farmers practice rain-fed agriculture. The stage of growth of the plant during plant development has been reported to influence the quantities of nutrients and chemicals in vegetables [3]. Throughout a plant's growth and development, the distribution of metabolites and nutrient levels in its various organs and tissues is constantly changing. This causes significant changes in a plant's nutritional composition at important stages of its growth cycle, such as vegetative, flowering, and senescence stage [4].

Post-harvest losses of perishable produce globally have been approximated to be about 20% - 60% for vegetables [5]. Tropical weather and underdeveloped infrastructure are factors in some Pacific, Caribbean, and African nations where these problems arise, and wastage rates can reach 40–50% [6]. Limited availability of appropriate and labor-saving technologies has been shown to contribute to the post-harvest losses [7]. Approximately, post-harvest losses in cowpea leaves and African indigenous vegetables (AIVs) can account for up to 30–40% of the overall yield, with other nations reporting considerably higher percentages [8]. There has been an increase in postharvest losses of leafy vegetables attributed to inappropriate harvesting stage and post-harvest management [9]. Intervening measures such as drying and processing to different forms would promote availability of cowpea leaves throughout the season and

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reduce the problem of massive post-harvest losses to farmers which normally result in high economic losses at the peak production period.

To protect and increase the keeping quality of vegetables, various drying methods have been used in the past. Functional chemicals and physical characteristics of green leafy vegetables change as a result of the post-harvest handling and drying method used [10]. Some of the frequently employed techniques include open sun drying, which entails exposing the food to solar radiation for a prolonged period of time without shielding it from the sun's UV rays. This results to carotenoids photodegrading and losing their vitamin A activity due to oxidation, isomerization, and/or the generation of free radicals [11]. Studies by Ndawula [12] revealed that *Amaranthus cruentus* lost up to 96.4% of its beta-carotene concentration. This therefore shows the importance of choosing the most favorable drying process for cowpea leaves and any other vegetable. Studies by Kirruti [13] showed that with the exception of magnesium and zinc, the mineral content of the chia leaves at various growth phases and after being dried using various techniques had a notable impact on the concentration of the minerals. For instance, chia leaves dried in an oven at the early vegetative stage contained the highest magnesium concentration (2.14 mg/100 g), whereas samples dried in a solar at the flowering stage contained the least concentration (1.64 mg/100 g) [13].

The maximum calcium content was found in oven-dried samples of chia leaves at the blossoming stage (1.49 mg/100 g), whereas the lowest calcium concentration was found in oven-dried samples of chia leaves at the early vegetative stage (0.41 mg/100 g). Chia leaf samples that were oven dried in the budding stage had the lowest zinc concentration, 1.27 mg/100 g, while those that were solar dried at the early vegetative stage had the highest concentration at 2.54 mg/100 g [13]. According to research by Naz [14], the alkaloid content of black night shade dried and harvested at the mature green berry stage had the highest value (1.07% w/w), while black night shade harvested at the 100% flowering stage and sun-dried had the lowest value. Regardless of the stage of harvest, the sun-dried food had the lowest alkaloid concentration.

The stage of harvesting a vegetable coupled with drying method significantly influences the quantity of nutrients retained. Correct harvesting stage at which the nutrients are maximum coupled with the right drying method ensures that all the nutrients required for human consumption are maximally conserved and utilized. Correct harvesting stage coupled with the wrong drying method may lead to significant losses in the nutritional quality of foods. This therefore means knowledge and information of integrating correct harvesting stages and the right drying methods will help in maximum processing and utilization of available nutrients in plants for improved food security healthy population. It is possible that if farmers harvest at the correct stage and use the right processing method, this can significantly influence the cowpea leaves nutrient composition. However, there is very little information available on the nutrient content of cowpea leaves harvested at different growth stages and dried using different drying methods. The purpose of this study was therefore to obtain information on best harvest stage with maximum nutrient content and best and safe drying method that will retain maximum nutrients and be adopted by farmers to solve the problem of seasonal availability of cowpea leaves and enhance food security.

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2. MATERIALS AND METHODS

2.1 Experimental Site

The study was carried out in Chuka Sub County, Tharaka Nithi County, Kenya. The cowpeas were planted in a farmers' field next to Chuka University horticultural demonstration farm. The farm lies at 0^{o} 19` S, $37^{o}$ 38` E and 1535 m above sea level. The region receives approximately

1,200 mm of rainfall annually, which is distributed bimodally, with the long rains falling from March to June and the short rains from October to December. The predominant soil type is humic nitisol, which is deep, well-weathered, and has moderate to high natural fertility and the average annual temperature is about 20 ^{o}C [15].

2.2 Experimental Design

The field experiment was set up using a randomized complete block design. The treatments included three harvesting stages i.e., 21, 35 and 49 days after sowing (DAS) while the laboratory three drying methods i.e., oven, open sun and solar drying which were laid in completely randomized design were used. Cowpea variety M66 was obtained from KALRO and planted in plots measuring 2 m by 2 m at a spacing of 70 cm between rows and 20 cm within rows. NPK 23:23:0 fertilizer was applied during planting and the plots were kept pest free.

2.3 Data Collection

Data collection was done over two cultivations, January-March and April-June 2022. Data collection was done sequentially following different stages of harvesting.

2.3.1 Determination of Nutrient Composition

Cowpea leaves were harvested at different growth stages i.e., 21, 35 and 49 DAS. The harvested leaves were then dried using the open sun, oven and solar after which nutrient analysis was done. Oven drying for nutrient analysis was done at 60 °C for 48 hours. Solar and open sun drying days was between 4-7 days depending on the weather conditions.

2.3.2 Moisture Content

Cowpea leaves (1g) were weighed, placed in a crucible and dried for eight hours at 105 °C to get a constant weight. The following formula was used to calculate moisture content;

Moisture= (weight of empty crucible weight of sample) - (weight of oven dried sample) ×100 divided by the weight of sample. The moisture content of the cowpea leaves was expressed in percentages.

2.3.2 Iron Content

The dried cowpeas leaf samples (0.2 g) were measured and put into microwave Teflon tubes and 6 mls of nitric acid was measured and added to the tube and 2 ml of H_2O_2 and put in an advanced microwave digester for 1 hour. After being taken out of the digester, the samples were filtered and diluted with distilled water till 50 ml mark of the volumetric flask The flask was inverted several times to ensure proper mixing. The mixture was then transferred to sample bottles ready for machine analysis. After the analysis the mineral content was read in an atomic absorption spectrophotometer model PG-990 (PG Instruments Limited, UK) [16].

2.3.3 Calcium Content

Dried cowpea leaf samples (0.2 g) were measured and put into microwave Teflon tubes, mixed with 6ml of nitric acid and 2 ml of H_2O_2 and put in an advanced microwave digester for one hour. After being taken out of the digester, the samples were diluted with distilled water and filtered. The volume of the sample was topped up to 50 ml mark of the volumetric flask and then the lid /top of the flask was put in place. The flask was inverted several times to ensure proper mixing. The mixture was then transferred to sample bottles ready for machine analysis. After the analysis the mineral content was read in an atomic absorption spectrophotometer model PG-990 [17].

2.3.4 Protein Content

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The proteins were determined using the Kjeldahl method [18]. Cowpea leaf sample (1g) was measured and put in digestion tubes (250 ml). Two Kjeldahl catalyst tablets (copper sulphate and potassium sulphate) were added into the digestion tube. 12 ml of concentrated H_2SO_4 was measured and poured into digestion tubes and then digested at 420 °C for one hour until liquid became clear or blue green appearance. The digester's exhaust manifold and digestion tube rack ere removed, and placed within a fume hood to cool till room temperature. Automatic distillation was then done with distilled water, standard NaOH solution and boric acid. The condensed liquid was then collected in flask with an indicator solution. Using HCl to titrate the solution, the trapped nitrogen in the boric acid produced a pink color. The protein content was calculated using the formula.

Protein content (%) = Titre value x M x 1.4007 x 6.25 x 100 /W where;

M= Molarity of the acid; W=Weight of test portion; 6.25=Conversion Factor

2.3.5 Beta-Carotene Content

Beta carotene concentration was determined using UV Spectrophotometer (Bioevopeak Co., Ltd, USA) and column chromatography as per Ahamad [19]. The cowpea leaf sample used weighed two grams (g). Using a mortar and pestle and little amounts of acetone, the color was removed until the residue was colorless. After being mixed into a 100 ml volumetric flask, all the extracts were dried in a rotary evaporator at a temperature of about 60 °C. 1 ml of petroleum ether was used to dissolve the beta-carotene in the evaporated sample through the densely packed column and the beta carotene was extracted. The eluent was placed in a volumetric flask measuring 25 ml, and the absorbance was measured at 450 nm. The beta-carotene standard curve was then used to determine the beta-carotene content.

2.3.6 Crude Fibre

The acid-alkali digestion method was used to estimate crude fibre as described in Sharma [20]. The digested residue was dried in a crucible, and weighed. In a muffle furnace, the dry residue was lit, and then weighed. The crude fibre weight was determined by dividing the two weights by their difference. Cowpea leaf sample weighing 1 g was placed in a beaker. 200 ml of Concentrated H_2SO_4 was measured, poured into the beaker containing the sample, heated, and then allowed to boil for 30 minutes. The sample was heated to boil before being filtered with a glass funnel and a cotton cloth. Thereafter, hot water was used to rinse the filtrate, and to neutralize the pH and remove any remaining acid. Sodium hydroxide 200 ml was measured and poured into the beaker with the filtered sample and placed into a hot plate and boiled for exactly 30 minutes. The sample was boiled, and then filtered once more in a conical flask with a discard flask using a glass funnel and cotton towel. The filtrate was once again rinsed with hot water to remove the acid residue to neutralize the pH. The filtrate emanating from the boiling in the alkali was put in a clean crucible. The crucible and the sample were placed on a hot plate to evaporate excess water. The sample was then dried for a further two hours at 130 °C in a hot oven before being removed and cooled. The dried fiber was weighed on a balance and weight noted

Crude Fibre = $W_1 – W_2$/SW X100

where;
W_1=Weight of the crucible with fibre; W_2=Weight of empty crucible; SW= Sample weight;

Acid insoluble ash= W_1- W_2/SW X100

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where;

W_1=Weight of crucible with ash; W_2=Weight of empty crucible ; SW= Sample weight

2.4. Data Analysis

The data on effect of harvesting stage and drying method on moisture content, calcium, iron, crude fibre, protein content, beta carotene was subjected to analysis of variance using the Statistical Analysis System version 9.3 at a 5% significant level. Significant means were separated using LSD at $\alpha = 0.05$.

3. RESULTS AND DISCUSSION

3.1. Effect of Harvesting Stage and Drying Method of Cowpea Leaves on Moisture Content

In trial one, harvesting at 21 DAS and open sun and solar drying, and also oven and solar drying did not significantly ($p<0.05$) differ in moisture content. However, harvesting at 21 DAS, and open sun and oven drying differed significantly ($p<0.05$) in moisture content. Harvesting at 35 DAS, and open sun drying did not differ significantly ($p<0.05$) from the solar drying. However, harvesting at 35 DAS and open sun and oven sun drying significantly ($p<0.05$) differed in moisture content. Harvesting at 49 DAS, and solar and oven drying were not significantly ($p<0.05$) different in the moisture content, but open sun differed significantly ($p<0.05$) from solar drying and it recorded the highest moisture content. Harvesting at 49 DAS, and solar, oven and open sun drying recorded a lower moisture content compared to harvesting at 21 DAS, and oven, solar and open sun drying of cowpea leaves.

In trial two, harvesting at 21 DAS and open sun and solar drying were not significantly ($p<0.05$) different in moisture content. Harvesting at 21 DAS and oven drying however differed significantly ($p<0.05$) from open sun drying and it recorded the least amount of moisture content (Table 1). Harvesting at 35 DAS and open sun drying significantly ($p<0.05$) differed from solar drying. Harvesting at 35 DAS and open sun drying recorded the highest moisture content. However, harvesting at 35 DAS and solar and oven drying did not significantly ($p<0.05$) differ in moisture content. Harvesting at 49 DAS and open sun and solar drying were not significantly ($p<0.05$) different in moisture content, however, open sun drying differed significantly ($p<0.05$) from oven drying in moisture content. Harvesting at 49 DAS and solar and oven drying were not significantly ($p<0.05$) different. The moisture content of cowpea leaves harvested at 49 DAS, and oven and sun drying reported a lower moisture content compared to harvesting at 21 DAS, and oven and sun drying. The interaction between the harvesting stage and the drying methods on moisture content was significant ($p<0.05$) in both trials (Table 1).

Trial, one showed that harvesting the cowpea leaves at 21,35 and 49 DAS, and open sun drying them differed significantly with solar and oven drying methods with the open sun recording the highest moisture content. This could have been caused by the difference in the duration of drying and also the difference in drying temperature. This finding is in agreement with Kirruti [13] who also reported that the stage of growth and drying method significantly ($p<0.05$) affected the moisture content of chia leaves. These results are also similar to those of Peter [21] who cited time and temperature at which drying process was done to greatly influence the final moisture content of dried tomato.

Table 1: Effect of harvesting stage and drying method on moisture content in percentage (%)

Harvest stage	Drying method	Trial one	Trial two

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21	Open-Sun	15.2^{ab}	14.94^{bc}
	Solar	13.52^{bcd}	14.67^{bcd}
	Oven	12.62^{cd}	11.83^{de}
35	Open-Sun	16.43^{a}	25.13^{a}
	Solar	14.77^{ab}	16.47^{b}
	Oven	13.75^{bcd}	14.20^{bcd}
49	Open-Sun	14.33^{c}	14.37^{bcd}
	Solar	12.05^{d}	13.14^{cde}
	Oven	12.00^{d}	10.20^{e}
LSD		1.8198	3.035
CV		11.28	17.38475
Harvest ×drying		P <.0001	P <.0001

* Means with different letters along the column are significantly different at $p \leq 0.05$. LSD is Least Significant Difference; CV is Coefficient of Variance

In trial two, harvest stage 21, 35 and 49 DAS, and open sun drying differed significantly with oven and solar drying methods in the dried cowpea leaves. This was caused by the variation in drying time and uniformity of the drying temperature. Oven dried cowpea leaves were dried at a constant temperature compared to the open sun- dried cowpea leaves which took a longer drying time and with uncontrolled drying temperatures. These findings are similar to those of Abugre [22] who reported a lower moisture content in oven drying *Cleome gynandra* flowers at 7weeks compared to sun drying *Cleome gynandra* flowers at 6weeks. However, these findings contradict Kirruti [13] who observed a high moisture content in the oven dried chia leaves at late vegetative stage. Trial two reported a higher moisture content on average compared to trial one. This could have been due to the fact that it was the rainy season compared to trial one which was done during the dry season.

3.2 Effect of Harvesting Stage and Drying Method on Iron Content

Harvesting at 21 DAS and open sun and solar drying were significantly ($p<0.05$) different in the iron content in trial one. However, oven and solar dried cowpea leaves were not significantly ($p<0.05$) different (Table 2). Harvesting at 35 and 49 DAS in oven, solar and open sun drying methods were not significantly ($p<0.05$) different in the iron content. In trial two, harvesting at 21 DAS in oven, solar and open sun drying did not significantly ($p<0.05$) differ in the iron content. Harvesting at 35 DAS, and oven and open sun were not significantly ($p<0.05$) different. However, solar and oven drying differed significantly ($p<0.05$) in the iron content. Harvesting at 49 DAS and solar and open sun, and oven and solar drying did not significantly ($p<0.05$) differ in the iron content (Table 2).

The iron content of cowpea leaves harvested at 35 DAS in oven, sun and solar drying contained a higher iron content in trial two compared to trial one. However, harvesting at 21 and 49 DAS and solar, oven and open sun drying had a higher iron content in trial one compared to trial two. The interaction between harvest stage and drying methods in the iron content were not significantly ($p<0.05$) different in trial one but differed significantly ($p<0.05$) in trial two (Table 2). Harvesting at 35 DAS and oven, solar and open sun drying did not differ significantly in iron content. Studies by Abugre [22] found that harvesting stage and drying method did not significantly ($p<0.05$) influence the iron content of spider flower *(Cleome gynandra).* The differences in iron content in the different drying methods and harvesting stages were attributed to different kinds of heat to which the cowpea leaves were exposed to. Heating has been reported to cause oxidative deterioration of iron, which result in release and decrease of the iron content in the dried leaves [23].

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Table 2: Effect of harvesting stage and drying method on iron content in grams (g)

Harvesting stage	Drying method	Trial one	Trial two
21	Open-Sun	1248.88^{a}	746.77^{ab}
	Solar	539.00^{c}	834.66^{ab}
	Oven	689.39^{bc}	779.92^{ab}
35	Open-Sun	524.60^{c}	673.82^{ab}
	Solar	457.86^{c}	503.19^{b}
	Oven	485.10^{c}	1026.03^{a}
49	Open-Sun	750.04^{bc}	628.24^{b}
	Solar	709.87^{bc}	569.68^{b}
	Oven	870.73^{abc}	692.23^{ab}
LSD		450.49	386.59
CV		27.06463	29.55479
Harvesting × Drying	P=0.0088		P=0.0257

* Means with different letters along the column are significantly different at p ≤0.05. LSD is Least Significant Difference; CV is Coefficient of Variance

The differences in iron content observed at harvest stage 35 DAS between solar and oven drying could have been due to differences in the duration of drying. Oven drying method had a controlled drying time and temperature and therefore oxidation process of iron was less compared to solar and sun drying methods. These findings agree with Khatoniar [24] who reported the highest amount of iron content in cabinet dried *Amaranthus spinosus* and lowest in sun dried *Rumex vesicarius*. Studies by Kiharason [25] also reported drying methods to significantly affect the amount of mineral iron of grounded pumpkin flour. The high iron content of cowpea leaves harvested at 21 and 49 DAS in all the drying methods could be attributed to unreliable rain, high temperatures and long dry period in the first trial compared to the second trial. This could have caused high evaporation of the soil moisture which resulted into increased soil water deficit therefore leading to accumulation of iron [26].

3.3 Effect of Harvesting Stage and Drying Method of Cowpea Leaves on Calcium Content

In trial one, harvesting at 21 DAS and solar and oven drying method did not differ significantly (p<0.05) in the amount of calcium content. However, the open sun significantly (p<0.05) differed with solar and oven drying (Table 3). Harvesting at 35 and 49 DAS and the open sun, solar and oven drying were not significantly (p<0.05) different in calcium content. In trial two, harvesting at 21 DAS and solar drying were significantly (p<0.05) different and also recorded the highest calcium content compared to oven and sun drying methods. Oven drying and open sun drying were not significantly (p<0.05) different in calcium content. Harvesting at 35 DAS, and the open sun, solar and oven drying did not significantly (p<0.05) differ in the amount of calcium content. Harvesting at 49 DAS and the open sun drying significantly (p<0.05) differed from solar and oven drying. However, the open solar did not significantly (p<0.05) differ with oven drying in the calcium content. Trial two had a higher calcium content in cowpea leaves harvested at 21 and 35 DAS compared to trial one. Harvesting at 49 DAS in trial one had a higher calcium content compared to trial two (Table 3). The interaction effect of harvest stage and drying method was significant in both trials.

Harvesting at 21 DAS and open sun drying method recorded the least calcium content. This could have been due to the young nature of the cowpea leaves at this stage and that the leaves were still growing in structure. It could also have been caused by the oxidation of calcium when

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exposed to the high uncontrolled drying temperatures of the open sun drying. Solar and open sun drying recorded high calcium content. The low calcium content in open sun-dried method could have been due to oxidation of calcium as a result of exposure to the high uncontrolled open -sun drying temperatures. These results contradict Kirruti [13] who reported that oven dried chia leaves samples at early vegetative stage had the lowest concentration of calcium.

According to studies done by Amoasah [27], oven-dried roselle calyces had the lowest calcium content (0.78%) while solar-dried roselle calyces had the highest calcium content (0.81%). These results however are contrary to Abugre [22] who observed that harvest stage and drying method did not significantly influence calcium content in spider flowers. The high calcium content in trial two compared to trial one could have been due to the high moisture content since it was done during the rainy season. Therefore, making the calcium easily absorbed by the cowpea leaves. Calcium is taken up by the plants through passive uptake and therefore calcium movement into the root and movement into the plant occurs along with the uptake of water [28]. The high calcium content in trial one at 49 DAS, could have been as a result of increased temperatures since it was done during the dry season causing evaporation which resulted in increased soil water deficit; therefore, increasing the calcium concentration [29].

Table 3: Effect of harvesting stage and drying method on calcium content in grams(g)

Harvesting stage	Drying method	Trial one	Trial two
21	Open-sun	3692.45^{c}	8227.95^{b}
	Solar	8433.16^{ab}	13433^{a}
	Oven	7606.18^{abc}	8361.78^{b}
35	Open-Sun	5667.03^{bc}	6380.06^{bc}
	Solar	6513.80^{abc}	7105.35^{bc}
	Oven	5764.65^{bc}	7123.15^{bc}
49	Open-sun	10064^{a}	6494.61^{b}
	Solar	9298.57^{ab}	5775.81^{c}
	Oven	7982.40^{ab}	5617.14^{c}
LSD		1059.8	2381.1
CV		25.48273	22.86227
Harvesting ×Drying		P< 0.0019	P <.0001

* Means with different letters along the column are significantly different at p ≤0.05. LSD is Least Significant Difference; CV is Coefficient of Variance

3.4 Effect of Harvesting Stage and Drying Method of Cowpea Leaves on Protein Content

In trial one, harvesting at 21, 35 and 49DAS, and oven, solar and open sun drying methods did not significantly ($p<0.05$) influence the protein content in the cowpea leaves (Table 4). In trial two, harvesting at 21 DAS and oven and solar drying methods were not significantly ($p<0.05$) different. However, Open sun drying significantly ($p<0.05$) differed from oven drying. Harvesting at 35 DAS, and oven drying and solar drying did not significantly ($p<0.05$) differ in the protein content. However, the open sun drying significantly ($p<0.05$) differed from solar and oven drying. Harvesting at 49 DAS and open sun and solar drying were not significantly ($p<0.05$) different in the amount of proteins content. Oven and solar drying and harvesting at 49 DAS were however significantly ($p<0.05$) different. Harvesting at 49 DAS and oven, solar and open sun drying recorded the least protein content. Trial, one had a higher protein content compared to trial two (Table 4). The interaction between harvesting stage and drying methods in both trials was significant ($p<0.05$) in the crude protein content.

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The high protein content recorded in the oven drying method could have been due to the low moisture in the oven dried cowpea leaves compared to those that were open sun dried. The low protein content in open sun drying method could have been due to increase denaturation of the proteins by the uncontrolled temperature. These findings are in agreement Abugre [22] who reported that the drying process significantly altered the relative composition of *Cleome gynandra L*, with crude protein (29.80 g/100 g) being higher in samples dried in the oven than in the sun. The low protein in open sun-dried leaves harvested at 35 DAS could have been as a result of the high moisture content and also increased utilization by the cowpea leaves. Oven drying recorded a higher protein content due to the low moisture content which led to an accumulation of proteins. It is possible that harvesting 49 DAS and oven, solar and open sun drying methods recorded the least protein content probably due to utilization of the stored proteins therefore resulting to reduced overall protein content.

Table 4: Effect of harvesting stage and drying method on protein content in percentage (%)

Harvesting stage	Drying method	Trial one	Trial two
21	Open-sun	29.14^{a}	25.43^{c}
	Solar	29.59^{a}	26.20^{bc}
	Oven	29.50^{a}	27.15^{b}
35	Open-sun	28.04^{bcd}	26.81^{bc}
	Solar	29.06^{ab}	28.86^{a}
	Oven	28.66^{abc}	29.74^{a}
49	Open-sun	27.70^{cd}	23.78^{de}
	Solar	27.23^{c}	23.07^{e}
	Oven	27.64^{cd}	25.37^{cd}
LSD		1.075	1.6559
CV		3.2389	5.414
Harvest ×Drying		P<.0001	P<.0001

* Means with different letters along the column are significantly different at p ≤0.05. LSD is Least Significant Difference; CV is Coefficient of Variance

The high protein content in trial one compared to trial two could have been as a result of the water stress since the trial one was done during the dry season. According to research by Silvente [30], water stress interfered with nitrogen metabolism, causing proteins to become more solubilized and amino acids to accumulate in soybean genotypes. Hence, the high temperatures in trial one might also have caused the elevated protein levels. Studies by Al-Ahmadi [29], reported a higher protein content during the dry season in all the samples tested compared to the wet season.

3.5 Effect of Harvesting Stage and Drying Method on Beta-Carotene Content.

In trial one, harvesting at 21 DAS, and solar and open sun drying did not significantly *(*p<0.05*)* differ in beta-carotene content (Table 5). However, oven drying significantly (p<0.05) differed with solar and the open sun drying. It also recorded the least beta carotene content. Harvesting at 35 DAS and open sun, solar and oven drying were not significantly (p<0.05) different in beta carotene. Harvesting at 49 DAS and open sun and solar drying did not significantly (p<0.05) differ in the beta carotene content. Oven drying significantly (p<0.05) differed with sun and solar drying. It also recorded the highest beta carotene content. In trial two, harvesting at 21 DAS and open sun and solar dried were not significantly (p<0.05) different in the amount of beta carotene. Solar and oven drying and harvesting at 21 DAS were not significantly (p<0.05)

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different (Table 5). Harvesting at 35 DAS and open sun and solar drying were not significantly (p<0.05) different Oven and solar drying and harvesting at 35 DAS were significantly (p<0.05) different in the beta carotene content. Harvesting at 49 DAS, and the open sun and solar drying did not significantly (p<0.05) differ in beta carotene content. However, oven drying significantly (p<0.05) differed with solar and open sun drying. Oven drying and harvesting at 49 DAS recorded the highest beta carotene content. The interaction between harvesting stage and drying method on beta carotene was significant (p<0.05) in both trials. Trial two had higher beta carotene content compared to trial one (Table 5).

Table 5: Effect of harvesting stage and drying method on beta carotene in milligrams (mg)

Harvesting stage	Drying method	Trial one	Trial two
21	Open-sun	17.20^{a}	18.75^{cde}
	Solar	17.46^{a}	16.29^{de}
	Oven	11.86^{bc}	24.16^{bcd}
35	Open-sun	7.61^{d}	21.32^{bcd}
	Solar	6.30^{d}	17.42^{de}
	Oven	8.68^{cd}	27.51^{b}
49	Open-sun	7.78^{c}	25.39^{bc}
	Solar	7.63^{c}	28.65^{b}
	Oven	$13.15g^{b}$	39.20^{a}
LSD		3.6928	7.8046
CV		19.22845	17.58494
Harvesting ×Drying		P<.0001	P<.0001

Means with different letters along the column are significantly different at p ≤0.05. LSD is Least Significant Difference; CV is Coefficient of Variance

The least beta carotene content was recorded when cowpea leaves were harvested at 21 DAS and oven dried. These could have been due to the fact that the cowpea leaves were very young and were still growing. This could have been caused by the controlled drying temperature in the oven that reduced the oxidation of the beta carotene. According to research by Bengtsson [31], the beta-carotene content of orange *C. Valencia* was reduced by 38.89, 52.42, and 87.14%, respectively, when the microwave, sun, and air oven methods were used. A Study by Akhila [32] on curry leaves and bitter gourd dried using oven at 60 °C and 90 °C respectively recorded high beta-carotene compared to those sun dried and shade dried. However, these findings contradict those of Shonte [33] results that a higher β-carotene content was reported in nettle leaves that were freeze-dried compared to oven dried leaves. Oven drying had the highest beta carotene content. This was due to controlled temperatures of the cowpea leaves in the oven drying method, which reduced the oxidation rate. Peter [21] while comparing the length of heating and various temperatures found that beta-carotene significantly decreased with temperature rise or increase in drying duration at a constant temperature Studies have reported beta carotene to be a water-soluble vitamin and heat sensitive and loses some of its potency when exposed to heat [34].

The high beta carotene content in trial two compared to trial one was attributed to differences in temperature levels since trial two was done during the rainy season when the temperatures were low compared trial one which was conducted during the dry season and the temperatures were high. These could have resulted to the increased oxidation of the beta carotene during trial one. The low beta carotene content could also have been caused by the increase in water stress in trial one compared to trial two. This observation is in agreement with Mibei [35], who

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noted a significant decline in carotenoids on African eggplant accessions under drought stress. Studies by Shonte [33] revealed the genotype of the plants, pruning and thinning, irrigation frequency, temperature, sunlight, fertilizer use, and soil fertility all had an impact on the accumulation of beta carotene by the plant tissues.

3.6 Effect of Harvesting Stage and Drying Method on Crude Fibre

In trial one, harvesting at 21 DAS and open sun, solar and oven drying methods were not significantly ($p \leq 0.05$) different in crude fibre content (Table 6). Harvesting at 35 DAS, and solar, open- sun and oven drying methods were also not significantly ($p \leq 0.05$) different in crude fibre. Harvesting at 49 DAS, and open sun, oven and solar drying methods were not significantly ($p \leq 0.05$) different in the crude fibre content. In trial two, harvesting at 21 DAS and solar drying the cowpea leaves significantly ($p \leq 0.05$) differed with oven and open sun drying methods. However, harvesting at 21 DAS, oven and open sun drying cowpea leaves were not significantly ($p \leq 0.05$) different in crude fibre content. Harvesting at 35 DAS, and oven and solar drying the cowpea leaves did not significantly ($p \leq 0.05$) influence the crude fibre content. However, open sun drying the cowpea leaves significantly ($p \leq 0.05$) differed from oven and solar drying methods. Harvesting at 49 DAS and open sun and solar dried cowpea leaves were not significantly ($p \leq 0.05$) different in crude fibre content. However, oven dried cowpea leaves differed significantly ($p \leq 0.05$) in crude fibre content (Table 6).

Table 6: Effect of Harvesting stage and Drying method on crude fiber in milligrams (mg)-

Harvesting stage	Drying method	Trial one	Trial two
21	Open-sun	13.97^{d}	14.42^{d}
	Solar	13.85^{d}	13.18^{c}
	Oven	13.48^{d}	14.81^{cd}
35	Open-sun	16.74^{abc}	13.57^{d}
	Solar	16.18^{c}	17.86^{bc}
	Oven	16.28^{bc}	19.32^{b}
49	Open-sun	17.63^{a}	20.39^{b}
	Solar	16.89^{abc}	20.85^{b}
	Oven	17.15^{ab}	26.32^{a}
LSD		0.9307	3.2307
CV		5.060719	15.53771
Harvesting ×Drying		P<.0001	P<.0001

* Means with different letters along the column are significantly different at $p \leq 0.05$. LSD is Least Significant Difference; CV is Coefficient of Variance

Comparison of the crude fibre content between the two trials showed that harvesting at 21 & 49 DAS, in trial two had a higher crude fibre content compared to trial one. However, harvesting at 35 DAS in trial one recorded a higher crude fibre content than trial two. The interaction of harvesting stage and drying methods significantly ($p \leq 0.05$) influenced the crude fibre content of the cowpea leaves in both trials (Table 6). Oven drying recorded the highest crude fibre content when cowpea leaves were harvested at 21 DAS. This could have been due to the low moisture content in the oven dried cowpea leaves. Harvesting at 21 DAS and oven drying had the highest fibre. These findings are in agreement with Lalita [36] who reported that hot air oven drying had significantly ($p \leq 0.05$) higher in dietary fibre in dried long bean and tomato than in sun drying in guava showing that changes in crude fibre content could be determined by the drying method and the type of crop. Oven drying of cowpea leaves harvested at 35 DAS recorded the highest crude fibre content.

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Yirankinyuki [37] found out that drying *leptadenia hastate* leaves- crude fibre content was higher in leaves dried using oven then solar and the least amount was observed in sun drying. Open sun recorded high fibre content when cowpea leaves were harvested at 49 DAS. This could have been due to the increased drying time by the open sun method compared to solar drying method. These findings contradict Garti [38] who reported a lower crude fibre content in *Hibiscus cannabinus* leaves that were shade dried compared to the sun-dried leaves. The steady rise in crude fiber content with growth stage was attributed to increased biosynthesis and the accumulation of crude fiber components over time [39]. The interaction effect of harvest stage and drying method in this study was significant and agreed with Kirruti [13] who also reported that interaction of harvest stage and drying method of chia leaves to significantly influence the crude fibre.

CONCLUSION AND RECOMMENDATIONS

The present study indicates harvesting the cowpea leaves at 35 DAS and adoption of solar and oven drying methods is best for maintenance of nutrient content in cowpea leaves over open sun drying method. This is because there are minimal losses in nutrient content. The simplicity of solar drying is a convenient option due to low-cost technology and ease of adoption. Oven-drying has a shorter drying time but high operating costs and adoption is dependent on farmer's capital. This research recommends adoption of solar dryers and oven dryers to dry leafy vegetables; and also, because they are affordable and efficient and in nutrient retention; in order to reduce seasonality in production and also reduce the post-harvest losses associated with excessive production.

REFERENCES-

[1]. Kirigia, D., Winkelmann, T., Kasili, R., & Mibus H. (2018). Development stage, storage temperature and storage duration influence phytonutrient content in cowpea (Vigna unguiculata L. Walp.). Heliyon. 2018;4: e00656. doi: 10.1016/j.heliyon. e00656.

[2]. Enyiukwu, D., Amadioha, A., & Ononuju, C. (2018). Nutritional significance of cowpea leaves for human consumption. *Greener Trends Food Sci Nutr*, *1*(1), 1-10.

[3]. Manyelo, T., Sebola, N., & Mabelebele, M. (2020). Nutritional and Phenolic Profile of Early and Late Harvested Amaranth Leaves Grown Under Cultivated Conditions. *Agriculture*, *10*(10), 432.

[4]. Adegbaju, O., Otunola, G., & Afolayan, A. (2019). Proximate, mineral, vitamin and anti-nutrient content of Celosia argentea at three stages of maturity. *South African Journal of Botany, 124,* 372-379

[5]. Dos Santos, S., Cardoso, R., Borges, Í., e Almeida, A., Andrade, E., Ferreira, I., & do Carmo Ramos, L. (2020). Post-harvest losses of fruits and vegetables in supply centers in Salvador, Brazil: Analysis of determinants, volumes and reduction strategies. *Waste Management*, *101*, 161-170.

[6]. Kiaya, V. (2014). Post-harvest losses and strategies to reduce them. *Technical Paper on Postharvest Losses, Action Contre la Faim (ACF)*, *25*, 1-25.

[7]. Mashau, M., Moyane, J., & Jideani, I. (2012). Assessment of post-harvest losses of fruits at Tshakhuma fruit market in Limpopo Province, South Africa. *African Journal of Agricultural Research*, *7*(29), 4145-4150. Dordrecht.

[8]. Owade, J., Abong', G., Okoth, M., & Mwang'ombe, A. (2020). A review of the contribution of cowpea leaves to food and nutrition security in East Africa. Food Science & Nutrition, 8(1), 36-47.

[9]. Elisha, G., Arnold, O., Christian, U., & Huyskens-Keil, S. (2016). Postharvest treatments of African leafy vegetables for food security in Kenya: a review. *African Journal of Horticultural Science,* 9.

[10]. De Martino, L., Caputo, L., Amato, G., Iannone, M., Barba, A., & De Feo, V. (2022). Postharvest Microwave Drying of Basil (Ocimum basilicum L.): The Influence of Treatments on the Quality of Dried Products. *Foods*, *11*(7), 1029.

[11]. Verduin, J., Den Uijl, M., Peters, R., & Van Bommel, M. (2020). Photodegradation products and their analysis in food. *J. Food Sci. Nutr*, *6*(67.10), 24966

[12]. Ndawula, J., Kabasa, J., & Byaruhanga, Y. (2004). Alterations in fruit and vegetable β-carotene and vitamin C content caused by open-sun drying, visqueen-covered and polyethylene-covered solar-dryers. African health sciences, 4(2), 125-130.

[13]. Kirruti, J., Mburu, M., & Njoroge, D. (2021). The Effect of Drying Processes on the Nutritional and Phytochemical Levels of Chia Leaves (Salvia hispanica L.) at Different Stages of Growth. *European Journal of Agriculture and Food Sciences*, *3*(6), 68-75.

[14]. Naz, A., Umesha, K., Smitha, G., Sreeramu, B., & Gowda, A. (2017). Influence of harvesting stages and drying methods on growth, yield and quality of black night shade (Solanum nigrum L.). *Medicinal Plants-International Journal of Phytomedicines and Related Industries*, *9*(3), 167-171.

[15]. Jaetzold, R., Schmidt, H., Hornetz, B., & Shisanya C. (2006). Farm Management Handbook of Kenya. Vol. II- Natural Conditions and Farm Management Information – 2nd Edition part B Central Kenya. Supbart B2. Central Province

[16]. Saywell, L. G., & Cunningham, B. B. (1937). Determination of iron: colorimetric o-phenanthroline method. *Industrial & Engineering Chemistry Analytical Edition*, *9*(2), 67-69.

[17]. Wu, D., Nie, P., He, Y., & Bao, Y. (2012). Determination of calcium content in powdered milk using near and mid-infrared spectroscopy with variable selection and chemometrics. *Food and Bioprocess Technology*, *5*, 1402-1410.

[18]. Kamizake, N. K., Gonçalves, M. M., Zaia, C. T., & Zaia, D. A. (2003). Determination of total proteins in cow milk powder samples: a comparative study between the Kjeldahl method and spectrophotometric methods. Journal of Food composition and analysis, 16(4), 507-516.

[19]. Ahamad, M. N., Saleemullah, M., Shah, H. U., Khalil, I. A., & Saljoqi, A. U. R. (2007). Determination of beta carotene content in fresh vegetables using high performance liquid chromatography. *Sarhad Journal of Agriculture*, *23*(3), 767.

[20]. Sharma, Y., Wadhawan, N., Lakhawat, S., Jain, S. K., & Babel, R. (2022). Analysis of nutritional composition of popular maize varieties.

[21]. Peter, A., John, J., & Sunday, T. (2010). Effect of Temperature and Drying Time on Some Nutritional Quality Parameters of Dried Tomatoes AU J.T. 14(1): 25-32

[22]. Abugre, C. (2011). Assessment of some traditional leafy vegetables of upper east region and influence of stage of harvest and drying method on nutrients content of spider flower (Cleome gynandra L.) (Doctoral dissertation).

[23]. Di Cesare, L., Forni, E., Viscardi, D., & Nani, R. (2003). Changes in the chemical composition of basil caused by different drying procedures. *Journal of Agricultural and Food Chemistry,* 51(12), 3575-3581.

[24]. Khatoniar, S., Barooah, M., & Das, M. (2019). Effect of different drying methods on micronutrient content of selected green leafy vegetables. *International Journal of Current Microbiology and Applied Sciences*, *8*(7), 1317-1325.

[25]. Kiharason, J., Isutsa, D., & Ngoda, P. (2017). Effect of drying method on nutrient integrity of selected components of pumpkin (Cucurbita moschata Duch.) fruit flour. *Journal of Agricultural and Biological Sciences, 12(3),* 110-116.

[26]. Kumar, A., Nayak, A., Das, B., Panigrahi, N., Dasgupta, P., Mohanty, S., ... & Pathak, H. (2019). Effects of water deficit stress on agronomic and physiological responses of rice and greenhouse gas emission from rice soil under elevated atmospheric CO2. *Science of the Total Environment*, *650*, 2032-2050.

[27]. Amoasah, B., Appiah, F., Tandoh, P., & Amoateng, E. (2019). Effect of different drying methods on the mineral content of three accessions of roselle (Hibiscus sabdariffa) calyces. *Asian J Adv Res Rep*, *5*(3), 1-10.

[28]. Yang, H., & Jie, Y. (2005). Uptake and transport of calcium in plants. *Journal of plant physiology and molecular biology*, *31*(3), 227.

[29]. Al-Ahmadi, M. (2014). Effects of dry and wet seasons on some soil minerals and proteins in some plants. *Journal of Environmental Science, Toxicology and Food Technology*, 01-06.

[30]. Silvente, S., Sobolev, A., & Lara, M. (2012). Metabolite adjustments in drought tolerant and sensitive soybean genotypes in response to water stress. *Plos one*, *7*(6), e38554.

[31]. Bengtsson, A., Namutebi, A., Alminger, M., & Svanberg, U. (2008). Effects of various traditional processing methods on the all-trans-β-carotene content of orange-fleshed sweet potato. *Journal of food composition and analysis*, *21*(2), 134-143.

[32]. Akhila, B., Shareena, K., & Rajesh, G. (2009). *Product diversification of jackfruit* (Doctoral dissertation, Department of Post-Harvest-Technology and Agricultural Processing).

[33]. Shonte, T., Duodu, K., & de Kock, H. (2020). Effect of drying methods on chemical composition and antioxidant activity of underutilized stinging nettle leaves. *Heliyon*, *6*(5), e03938.

[34]. Chen, L., Bai, G., Yang, R., Zang, J., Zhou, T., & Zhao, G. (2014). Encapsulation of β-carotene within ferritin nanocages greatly increases its water-solubility and thermal stability. *Food chemistry*, *149*, 307-312.

[35]. Mibei, E., Ambuko, J., Giovannoni, J., Onyango, A., & Owino, W. (2017). Carotenoid profiling of the leaves of selected African eggplant accessions subjected to drought stress. *Food Science & Nutrition*, *5*(1), 113-122.

[36]. Lalita, S., & Jiradech, M. (2016). Effect of Drying Methods On Dietary Fiber Content in Dried Fruit and Vegetable from Non-Toxic Agricultural Field. International Journal of GEOMATE, Dec., 2016, Vol. 11, Issue 28, pp.2896-2900

[37]. Yirankinyuki, F., Danbature, W., Muzakir, M., & Simon, S. (2015). Chemical composition and nutritive value of leptadenia hastata leaves. *Int. J. Innov. Sci. Res*, *4*, 480-484.

[38]. Garti, H., Agbemafle, R., & Ibrahim, A. (2018). Effects of shade and sun drying on nutrient composition of hibiscus cannabinus.

[39]. Lorenz, K., & D'Appolonia, B. (1980). Cereal sprouts: composition, nutritive value, food applications. *Critical Reviews in Food Science & Nutrition*, *13*(4), 353-385.