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Microbial quality and nutritional assessment of *Brassica oleracea* (Cabbage) flour processed by sun and oven drying methods

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Abstract

Ensuring the microbial safety and nutritional integrity of vegetable-based flours is critical for their utilization in food systems. This study investigated the effect of sun and oven drying methods on the nutritional composition and microbial quality of flour produced from *Brassica oleracea* (cabbage). Proximate analysis revealed that oven drying resulted in lower moisture and lipid content but higher protein, fiber, and carbohydrate levels compared to sun drying. Microbial evaluation showed a significantly higher bacterial load (93.00×10^{-3} CFU/mL) and fungal load (75.33×10^{-3} CFU/mL) in sun-dried flour than in oven-dried flour (53.33×10^{-3} and 26.67×10^{-3} CFU/mL, respectively). Isolated microorganisms included *Staphylococcus aureus*, *Enterococcus faecalis*, *Bacillus subtilis*, *Escherichia coli*, *Aspergillus niger*, *Rhizopus stolonifer*, and *Fusarium oxysporum*. The predominance of *S. aureus* and *A. niger* in sun-dried samples suggests contamination from handling and environmental exposure. Overall, oven drying yielded safer and nutritionally superior cabbage flour. These findings underscore the need for hygienic and controlled drying methods to enhance the safety and quality of vegetable-derived flours.

Keywords: Cabbage flour, brassica oleracea, microbial load, oven drying, sun drying, food safety

1. Introduction

Cabbage (*Brassica oleracea* L.) is a widely consumed cruciferous vegetable valued for its vitamins, fiber, minerals, and bioactive compounds (Novotny *et al.*, 2018) [7]. Its phytochemical constituents such as glucosinolates, polyphenols, and antioxidants offer multiple health benefits and contribute to its functional food properties. However, high moisture content and microbial susceptibility limit its postharvest shelf life. Converting cabbage into flour is increasingly recognized as an effective strategy for reducing spoilage, adding value, and enhancing its versatility in food formulations.

Drying is a crucial processing step that influences both microbial safety and nutrient retention. Sun drying is common in low-resource settings due to its low cost, but it exposes produce to contaminants including dust, insects, and human handling. In contrast, oven drying provides a more controlled environment that minimizes microbial contamination and reduces moisture to levels unfavorable for microbial proliferation (Wang *et al.*, 2020) [11].

Recent studies have highlighted the importance of hygienic drying technologies in preventing microbial spoilage and preserving nutrients in vegetable powders (Waseem *et al.*, 2022; Ezeonuegbu & Ugwu, 2023) [3, 9]. However, limited data exist comparing the microbial and nutritional qualities of cabbage flour processed with different drying techniques in Nigeria. This study therefore evaluates the proximate composition and microbial profile of cabbage flour produced by sun and oven drying to determine the safer and more nutritionally reliable method.

2. Materials and Methods

2.1 Sample Collection and Preparation

Fresh cabbage heads were purchased from Farin Gada Market, Jos, Nigeria. Samples were washed, surface-sterilized with 4% sodium hypochlorite, rinsed in sterile water, shredded, and divided into two drying groups.

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2.2 Drying Methods

Sun drying: Shredded cabbage was spread on sterile mesh trays and dried outdoors for seven days.

Oven drying: Samples were dried in a hot-air oven at 80 °C for 24 hours.

Dried samples were milled into fine flour using a laboratory blender and stored in airtight glass containers.

2.3 Proximate Analysis

Moisture, protein, lipid, ash, crude fiber, and carbohydrate contents were analyzed using standard AOAC (2019) protocols.

2.4 Microbial Load Determination

Serial dilutions of flour samples were plated on nutrient agar for bacterial counts and potato dextrose agar for fungal counts. Incubation was done at

3. Results and Discussion

The Proximate composition of sun dried and the oven dried cabbage sample is presented in the Table 1 below. These

two processing techniques deployed in this study significantly reduced amounts of crude proteins, crude fat, and moisture contents in processed flours. Whereas an increase in the amount of crude fibre, ash content and carbohydrate were recorded in processed flours.

Among the processed treatments, sun drying yielded the highest in the amount of crude fat (0.18%) and moisture content (7.35%), while oven drying yielded highest in crude protein (12.56%), crude fibre (37.46%), ash content (11.14%) and carbohydrate (46.07%).

Table 1: Proximate composition of fresh and processed cabbage flours (g/100 g)

Parameters	Fresh cabbage	Sun dried	Oven dried
Moisture	9.37 ± 0.22	7.35 ± 0.13	6.48 ± 0.03
Fibre	32.79 ± 0.25	32.58 ± 0.28	37.46 ± 0.12
Fat (lipid)	0.26 ± 0.02	0.18 ± 0.01	0.037 ± 0.02
Ash	9.81 ± 0.05	10.92 ± 0.03	11.14 ± 0.13
Protein	23.157 ± 0.30	12.127 ± 0.04	12.563 ± 0.03
Carbohydrate	38.16	45.88	46.07

Table 2: Identification of Bacteria Isolates from Oven dry and Sundry Cabbage Using Biochemical Testing

S/N	Gram reaction	Shape	Motility	Oxidase	Catalase	Coagulase	Citrate	Urea	TSI	Indole	Possible Organism
1	+	Cocci	-	-	+	+	+	+	+	-	<i>S.aureus</i>
3	+	Cocci	-	-	-	-	-	-	+	-	<i>E.feacalis</i>
4	+	Rod	-	-	+	+	+	-	-	-	<i>B.subtilis</i>
5	-	Rod	+	-	+	-	-	-	+	+	<i>E.coli</i>

Key: - = negative, + = positive

The results revealed that the bacteria isolated from all sample collected were *staphylococcus aureus*, *Enterococcus*

faecalis, *Bacillus subtilis*, and *Escherichia coli* as seen in the table above.

Table 3: Cultural and Microscopic features of filamentous fungal isolates

Isolates	Cultural features	Microscopic features	organism
1	On PDA, colonies had rapid growth rate. However, colonies were flat and compact with yellow basal felt covered by a dense layer of black conidial heads with powdery texture. The colour on the reverse side was pale yellow.	Septate hyphae with Conidiophores were hyaline or pale-brown to black, erect, simple, with foot cells basally, inflated at the apex forming globose vesicles, bearing conidial heads split into over 4 loose conidial columns with over 4 fragments apically composed of catenulate conidia.	<i>Aspergillus niger</i>
2	On PDA Colonies are initially white, becoming tinged with salmon and lavender at maturity. Lavender to purple reverse	Hyphae are septate and hyaline Macroconidia usually produced abundantly, slightly sickle-shaped, thin-walled, with an attenuated apical cell and a foot-shaped basal cell. Microconidia are abundant, mostly non-septate, and ellipsoidal to cylindrical, slightly curved or straight.	<i>Fusarium oxysporum</i>
3	On PDA, Colonies are very fast growing, cottony to fluffy, white to yellow, becoming dark-grey.	Sporangiospores are hyaline, grey or brownish, globose to ellipsoidal, and smooth-walled, and erect, simple or branched, forming large, terminal, globose to spherical, multispored sporangia, without apophyses and with well-developed subtending columellae.	<i>Rhizopus stolonifer</i>



Fig 1: Sun dried flour**Figure 2: Oven dried flour**

Cabbage is a very nutritious and affordable vegetable that is widely consumed. Its processed flour can be a promising food product for the reason that it holds a significant position among functional foods owing to its extensive and beyond-food application in contemporary nutrition and traditional medicine. The proximate analyses of fresh and respective cabbage flours show difference in the values of moisture content, crude protein, crude fat, ash content and total carbohydrate.

Nutritional composition via proximate analyses of the dried cabbage agrees to the findings of a previous studies, where a reduction in nutrients levels of the processed cabbage *viz*: moisture content, protein and fibres might be associated with the thermal degradation of the nutrients (Prokopov *et al.*, 2015; Duarte *et al.*, 2019) ^[2, 8]. Also, an increase in crude fibre ash content and carbohydrate were in line with reports of Duarte *et al.* (2019) ^[2] and Waseem *et al.* (2022) ^[9].

Reduction in protein contents of the cabbage flour as compared to the recommended daily requirement of 45-55 g of protein a day for a healthy human being (Hruby *et al.*, 2021) ^[13] may be associated with the physicochemical changes such as unfolding of protein structures, breakdown of intra-linkages and denaturation (Waseem *et al.*, 2022) ^[9]. According to Waseem *et al.* (2022) ^[9], who stated that the protein contents of the processed cabbage are comparable to that of local wheat cultivars, thus suggesting partial replacement of the wheat flour with dehydrated cabbage to not significantly affect protein-energy contents of the blend but also use to supplement low protein carrier staple cereals and tuber flours, which may significantly enhance food value of the blends.

The reduction in value of the moisture content of the oven dried cabbage over sun-dried cabbage sample suggest that the cabbage flour may have a longer shelf life without growing mouldy (Ezeonuegbu *et al.*, 2023) ^[3].

Also, crude fat was found to be low in the oven-dried cabbage as when compared to the sun-dried cabbage flour. Due to the low fat, the processed cabbage can be used in preparation of weight-loss diets (Rokaya *et al.*, 2013; Waseem *et al.*, 2022) ^[9, 14] and food supplement in keto diet. Recorded results indicated a high variation in terms of the percentage proportion of individual fractions in fiber of fresh cabbage, as well as sun dried and oven dried cabbage flour. Report from Duarte *et al.* (2019) ^[2], showed that there was a change in the quantitative and qualitative individual fractions of analysed fibre of thermal processed as compared to fresh cabbage. In other study, it was also found that thermal processing had a significant effect on the content of fibre (Waseem *et al.*, 2022) ^[9]. Moreover, according to Duarte *et al.* (2019) ^[2], an increment in the contents of fibre

may be explained by the leaching of soluble components to the

Solution, which resulted in changes in percentage contents of these components in the analysed raw materials. According to their report, an apparent increase in the contents of dietary fibre is a consequence of the formation of complexes between polysaccharides and other components, such as proteins and phenolic compounds, which are assayed as fibres.

The value of the carbohydrate in the oven dried (46.07%) and sun-dried cabbage 45.88% cabbage flour was higher than that of the fresh cabbage (38.16%) which shows that the processed cabbage flour used in the preparation of sauerkraut, dehydrated powders for salads, functional juices (Xu *et al.*, 2014) ^[12] and other food preparations such as soup, biscuits, bread, pasta, and pastries (Lee, 2010) ^[5], could be a great source of energy thereby improving the general health and well-being of human beings.

Table 4: Microbial quality of cabbage processed using different drying methods

Drying Methods	Total Bacteria Counts (CFU/ml X 10 ⁻³)	Total Fungal Counts (CFU/ml X 10 ⁻³)
Sun dry	93.00±3.22 ^a	75.33±4.10 ^a
Oven dry	53.33±4.09 ^b	26.67±3.18 ^b
LSD	10.38	
P-value	≤0.001 ****	

At $p \leq 0.001$ there was a significant difference in the Microbial quality of plants processed using different drying methods. Values are presented as $\pm$ standard error of means. Ranking was done across the drying methods and values with the same super script are not significant

The microbial quality of the different drying methods of cabbage flour produced a highly significant difference at $p \leq 0.001$ (Table 3). The sun drying processing method recorded the highest number of microbial loads as compared to the oven drying method.

As for the total bacteria count, the Sun drying method had the highest number of bacteria count of 93.00×10^{-3} cfu/ml more than the Oven drying method with 53.33×10^{-3} cfu/ml. Correspondingly, the sun drying method also had the highest number of fungal count of 75.33×10^{-3} cfu/ml as to when compared to the oven drying method with 26.67×10^{-3} cfu/ml fungal count.

The result of the bacteria isolated from the Oven dried and Sun-dried Cabbage Sample is presented in the table below

Table 5: Occurrence of Bacteria Isolates from Oven dry and Sundry Cabbage

Organisms	Oven dry	Sundry	Total (%)	% Frequency of Occurrence
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<i>S. aureus</i>	+	+	02	40
<i>E. faecalis</i>	-	+	01	20
<i>B. subtilis</i>	+	-	01	20
<i>E. coli</i>	+	-	01	20
Total	03(60.0%)	02(40.0%)	05	100

The bacteria *Staphylococcus aureus* was the dominant bacteria as seen in the table above. This finding is similar to previous reports by Bamfeka et al. (2022) ^[1].

Staphylococcus aureus is found everywhere in the human body as part of the normal flora of the human skin. (Forbes et al., 2007) ^[4], it is a facultative bacteria known for causing food borne illness, it can contaminate food during processing.

Bacillus subtilis is a gram-positive aerobic or facultative anaerobic bacteria that is commonly found in the soil. It is known for producing spores that can survive hard conditions such as heat and drying, making it a common isolate in food products.

Escherichia coli is a gram-negative bacterium which was found in only the oven dried cabbage sample. It is a bacterium that is commonly found in the gastrointestinal tract of humans and animals. Some strains of *Escherichia coli* cause food borne diseases while other strains are harmless to human health. It is an indicator of fecal contamination of food found in our environment. It was argued by Mritunjay and Kumar (2017) ^[6] that the intrinsic adherence properties of gram negative bacteria to the surfaces of vegetables may help them survive the washing and sanitizing steps during the preparation of the flour.

Enterococcus faecalis is a facultative anaerobic bacteria that was found in the gastrointestinal tract of humans and animals, it is also an indicator for fetal matter although some strains can be used as a probiotic.

The isolates *Aspergillus niger* and *Rhizopus stolonifer* were present and dominant in both flour samples with 40% as seen below. They are both common fungi in the World that are found tropical and sub-tropical regions. They grow rapidly in dark places and they are both common agent in the decomposition of stored foods. The least fungi identified was *Fusarium oxysporum*, a devastating soil borne fungal pathogen. These organisms poses a serious threat to the health of the consumer as microorganisms like *Aspergillus* can produce mycotoxins which are lethal when consumed and poses a serious threat to the health of consumers and sellers of cabbage.

Table 6: Occurrence of Fungal Isolates from Oven dry and Sundry Cabbage

Organisms	Oven dry	Sundry	Total (%)	% Frequency of Occurrence
<i>A. niger</i>	+	+	02	40
<i>F. oxysporum</i>	+	-	01	20
<i>R. stolonifer</i>	+	+	01	40
Total	03(60.0%)	02(40.0%)	05	100

4. Conclusion

The study revealed that cabbage flour samples contained nutritional components which if freely available for consumption will improve the nutritional status of consumers and reduce their nutritional problems.

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