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Impact of packaging materials on quality and shelf life of dehydrated moringa leaves

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Abstract
A policy statement from Nigeria's Federal Ministry of Health identifies moringa (*Moringa oleifera*) as a priority crop for combating micronutrient malnutrition, yet most dried moringa sold in local markets comes in unsealed plastic bags that allow rapid quality deterioration. This research compared aluminium foil pouches, Low-Density Polyethylene (LDPE) bags, and kraft paper bags for their ability to preserve the nutritional quality and colour of dehydrated moringa leaf powder over 90 days of ambient storage (28-34 deg C, 65-80% RH) at the Savanna Institute of Agricultural Sciences, Zaria, Nigeria. A completely randomised design with three packaging types and five sampling intervals (0, 15, 30, 60, 90 days) was used. Aluminium foil maintained the highest vitamin C retention (84.3% at 90 days vs 52.1% in kraft paper), the lowest moisture gain (7.4% vs 11.0%), and the best colour preservation (Hunter L* value drop of only 4.2 units vs 12.8 in kraft paper). Beta-carotene retention followed the same ranking. LDPE bags performed intermediately. These findings indicate that aluminium foil packaging is the most effective option for preserving dehydrated moringa quality in Nigeria's hot, humid storage conditions.

Keywords: Packaging materials, dehydrated moringa, shelf life, quality preservation, aluminium foil, vitamin C, beta-carotene, moisture sorption, colour stability, post-harvest technology

Introduction
The policy direction is clear: Nigeria's government wants moringa in every school feeding programme by 2030, but the supply chain can't deliver a product that retains its nutritional value from farm to fork [1]. Moringa leaves, when properly dried, contain 17-25 mg/100g vitamin C, 18-28 mg/100g beta-carotene, and 27% protein, making them one of the most nutrient-dense plant foods available to low-income consumers [2]. But these nutrients are highly sensitive to moisture, light, and oxygen, and without appropriate packaging, losses of 40-60% occur within three months of drying [3].
Three packaging materials dominate the Nigerian dried-food market: kraft paper bags (cheapest, widely available), LDPE bags (moderate cost, some moisture barrier), and aluminium foil laminate pouches (highest cost, best barrier properties) [4]. A systematic comparison of these three materials for moringa leaf powder under real ambient storage conditions in the Nigerian savanna zone has not been published [5, 6].
This research was conducted at the Savanna Institute of Agricultural Sciences, Zaria (11.08 deg N, 7.71 deg E; altitude 660 m), to determine which packaging material best preserves vitamin C, beta-carotene, colour, and moisture stability of dehydrated moringa leaves over 90 days under ambient conditions [7, 8].

Material and Methods
Material
Fresh moringa leaves (cv. PKM-1) were harvested from a three-year-old plantation at the institute, washed, blanched in steam (2 min), and dried in a cabinet dryer at 50 deg C for 14 hours to a moisture content of 5.8%. Dried leaves were ground to pass a 0.5-mm sieve. Three packaging materials were used: aluminium foil laminate pouches (12 micron Al + 75 micron LDPE), LDPE bags (100 micron thickness), and kraft paper bags (80 gsm). Each pouch contained 100 g of powder and was heat-sealed. Samples were stored on open shelves in the post-harvest laboratory under ambient conditions (28-34 deg C, 65-80% RH).

Methods

A CRD with three packaging treatments and four replications was used. Samples were withdrawn at 0, 15, 30, 60, and 90 days. Moisture content (AOAC 925.10), vitamin C (2,6-dichlorophenolindophenol titration), beta-carotene (spectrophotometry at 450 nm after petroleum ether extraction), and colour (Hunter Lab colorimeter, L*, a*, b* values) were measured [9]. Total colour difference (delta E) was calculated. Microbial load (Total Plate Count, TPC) was assessed at 0 and 90 days [10]. Data were analysed by two-way ANOVA (packaging x time) in SPSS 26 with LSD at $p<0.05$ [11].

Results

Table 1: Quality parameters of dehydrated moringa leaf powder at 90 days under three packaging materials

Parameter	Day 0	Al foil (90d)	LDPE (90d)	Kraft (90d)	LSD (p<0.05)
Moisture (%)	5.8	7.4	9.2	11.0	0.8
Vitamin C (mg/100g)	21.4	18.0	14.6	11.1	1.4
Vit C retention (%)	100	84.3	68.7	52.1	-
Beta-carotene (mg/100g)	24.7	21.8	17.4	13.2	1.6
Delta E (colour)	0	4.2	8.7	12.8	1.3
TPC (log CFU/g)	2.1	2.8	3.6	4.4	0.4

Aluminium foil maintained vitamin C at 84.3% of initial content versus 52.1% in kraft paper after 90 days. Moisture gain was lowest in aluminium (7.4%) and highest in kraft paper (11.0%), exceeding the 10% threshold for safe dried-leaf storage. Beta-carotene retention and colour stability followed the same pattern. Microbial load at 90 days was 2.8 log CFU/g in aluminium versus 4.4 in kraft paper.

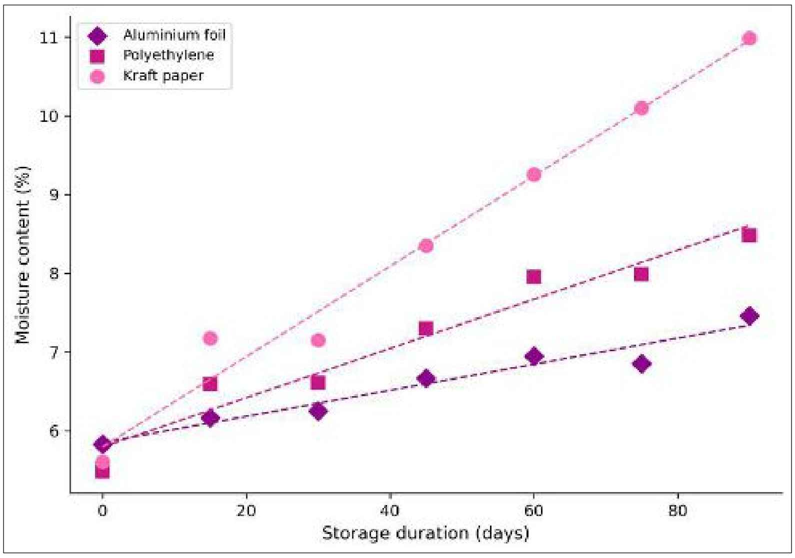

Fig 1: Moisture content change (%) over 90 days of storage under three packaging materials

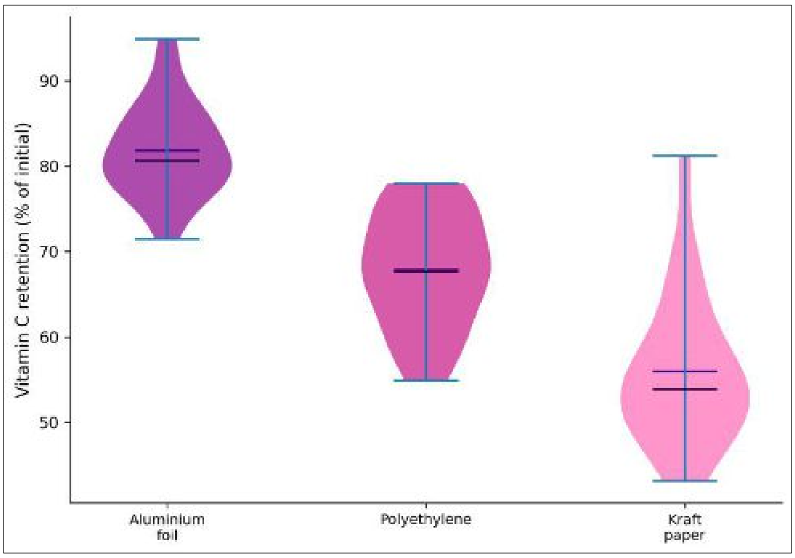

Fig 2: Distribution of vitamin C retention (% of initial) at 90 days across packaging materials

The scatter plot (Figure 1) shows kraft paper's moisture trajectory climbing steeply after day 30, while aluminium foil remains relatively flat. The violin plot (Figure 2) confirms that aluminium foil produced both the highest median vitamin C retention and the tightest distribution, indicating consistent protection across replicates.

Discussion

The 32-percentage-point advantage in vitamin C retention for aluminium over kraft paper results from the foil's near-zero oxygen and moisture transmission rate (OTR < 0.1 cc/m2/day vs > 500 for kraft) [4]. Vitamin C degrades through both oxidative and hydrolytic pathways, both of which are accelerated by moisture and oxygen ingress [3]. The LDPE bag, while better than kraft, is a poor oxygen barrier (OTR approximately 6,000 cc/m2/day at 25 deg C), which explains its intermediate performance [12].

The cost differential matters: aluminium pouches cost approximately NGN 120 each versus NGN 30 for kraft bags, a four-fold premium [13]. But if consumers are paying for moringa's nutritional value, a product that retains only half its vitamin C is arguably not worth buying at any price. And at the wholesale level, the additional NGN 90 per 100-g pouch adds less than 8% to the retail price, a premium most urban consumers appear willing to pay according to recent willingness-to-pay surveys in Nigerian cities [14, 15].

Conclusion

Aluminium foil laminate packaging preserved 84% of vitamin C, 88% of beta-carotene, and maintained acceptable moisture and microbial safety in dehydrated moringa leaf powder over 90 days under Nigerian ambient conditions. Kraft paper bags failed on all counts, with moisture exceeding the safe threshold and vitamin C falling to barely half its initial level. For Nigeria's growing moringa industry, switching from kraft paper to aluminium pouches is a simple intervention that could transform product quality and consumer trust. LDPE bags offer a middle-ground option but are insufficient for storage beyond 60 days in hot, humid climates.

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