

Structure, Actor Roles, Product Flows and Value Addition in the Moringa Product Value Chain in Semi-Arid Makueni County, Kenya

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ABSTRACT

Moringa has increasing potential as a multipurpose agricultural commodity in semi-arid areas because its leaves, seeds and other products can be marketed in both raw and processed forms. However, limited empirical evidence exists on the organization, functional roles, product flows and value addition processes that shape the Moringa product value chain in semi-arid Kenya. This study examined the structure and functioning of the Moringa product value chain, identified the roles of participating actors, assessed product flows and value addition, and examined constraints affecting commercialization in Kibwezi East and West Sub-Counties of Makueni County, Kenya. A descriptive cross-sectional survey was conducted among 650 value-chain actors comprising 167 producers (25.7%), 90 middlemen/brokers (13.8%), 108 retailers (16.6%), 63 wholesalers (9.7%), 12 processors (1.8%) and 210 consumers (32.3%) across Makindu, Emali, Masongaleni and Thange Wards. Data were collected using structured questionnaires and analysed using descriptive statistics, cross-tabulations and chi-square tests in SPSS version 26. Value-chain mapping was used to characterize product, financial and information flows among actors. The results showed that the Moringa value chain comprised interconnected producers, brokers, wholesalers, processors, retailers and consumers, although the intensity of participation varied spatially. Broker participation differed significantly across wards ($\chi^2 = 79.69$, $p < 0.001$), as did retailer participation ($\chi^2 = 19.07$, $p < 0.001$) and processor participation ($\chi^2 = 11.30$, $p = 0.010$), whereas differences in producer and wholesaler participation were not statistically significant. Fresh leaves and seeds were the most widely marketed products, while dried leaves, flowers and seed oil represented important diversification opportunities. Approximately 72.3–73.7% of Moringa production was marketed, while 26.3–27.0% was retained for household consumption, demonstrating a predominantly commercial orientation. Value addition substantially increased product value. Fresh leaves generated net value added of KSh 17–20/kg, compared with KSh 300–420/kg for dried leaf powder, KSh 55–225/kg for seeds and KSh 1,080–1,620/kg for seed oil across the study wards. Higher-value processing was nevertheless concentrated among a small proportion of actors, reflecting constraints in processing facilities, technical skills, finance, market information, transport and market linkages. The study concludes that the Moringa value chain in semi-arid Makueni County is commercially active but unevenly developed. Strengthening decentralized processing, producer organization, access to finance, market information, product quality systems and linkages between producers and processors would improve value capture and support inclusive commercialization.

Keywords: Moringa, value chain, value addition, commercialization, semi-arid agriculture, Makueni County, Kenya

INTRODUCTION

Agricultural value chains provide an important framework for understanding how agricultural commodities move from production to final consumption and how value is created and distributed among participating actors. A value chain encompasses not only the physical movement of products but also the services, information, finance, technologies and relationships that connect actors at different stages of production, processing and marketing (Kaplinsky & Morris, 2002; Gereffi et al., 2005). Understanding these relationships is particularly important for agricultural commodities produced in semi-arid environments, where production risks, limited infrastructure, weak market integration and restricted access to productive resources can constrain commercialization.

Moringa is increasingly recognized as a multipurpose tree with nutritional, medicinal, environmental and economic importance. *Moringa oleifera* is particularly important because its leaves, seeds, flowers, pods and other plant parts can be consumed or transformed into commercially valuable products. Moringa leaves can be sold fresh or processed into dried leaf powder, while seeds can be marketed directly or transformed into oil and other products. Such diversification creates opportunities for extending shelf life, reducing post-harvest losses and increasing the economic value captured along the chain.

The potential of Moringa is particularly relevant in semi-arid regions of Kenya. Semi-arid agricultural systems are characterized by climatic variability, recurrent moisture stress and production uncertainty, making diversification into multipurpose and relatively drought-tolerant crops an important livelihood strategy. Moringa can contribute to this diversification through simultaneous provision of food, household nutrition, income and raw materials for small-scale processing. Its multiple products also create opportunities for different categories of value-chain actors, ranging from smallholder producers and local traders to processors and retailers. However, production of a commodity does not necessarily translate into equitable economic benefits for producers. Value is progressively created through aggregation, sorting, grading, drying, milling, extraction, packaging, branding, transportation and marketing. The distribution of these functions influences which actors capture economic value and which actors remain concentrated at lower-value stages of the chain. Value-chain upgrading may therefore involve product transformation, improved processes, stronger market relationships, better organization or movement into higher-value functions (Gereffi et al., 2005; Gereffi & Fernandez-Stark, 2016).

Previous studies have established the importance of Moringa for livelihoods, nutrition and income generation, but empirical evidence on the organization and functioning of Moringa value chains in semi-arid Kenya remains limited. Existing research has tended to focus on production, nutritional characteristics, adoption or individual marketing aspects rather than examining the chain as an interconnected system involving producers, intermediaries, processors, wholesalers, retailers and consumers. There is therefore a need to understand how actors are distributed, what functions they perform, how products move between them, where value addition occurs and what constraints limit upgrading.

This study addresses this gap by examining the structure and functioning of the Moringa product value chain in Kibwezi East and West Sub-Counties of Makueni County. Specifically, the study sought to: (i) characterize the distribution of Moringa value-chain actors; (ii) identify the functional roles performed by producers, brokers, wholesalers, processors, retailers and consumers; (iii) examine the products marketed and their movement through the chain; (iv) assess production, sales and household consumption patterns; (v) examine value addition and economic returns associated with major Moringa products; and (vi) identify constraints affecting commercialization and value-chain upgrading.

The study contributes empirical evidence on the organization of a developing Moringa value chain in a semi-arid agricultural setting and identifies opportunities for improving value capture through processing, coordination and market development.

LITERATURE REVIEW

Agricultural Value-Chain Analysis

The value-chain concept emphasizes the sequence of activities through which products acquire value before reaching final consumers. Porter (1985) conceptualized value creation as a series of interconnected activities, while Kaplinsky and Morris (2002) extended the approach to development contexts by emphasizing the distribution of value among participants and opportunities for upgrading. Agricultural value chains involve numerous actors performing specialized functions. These include input suppliers, producers, aggregators, brokers, processors, wholesalers, retailers and consumers. Gereffi et al. (2005) emphasized that value chains should be understood not only in terms of transactions but also in terms of governance, coordination and power relationships among actors. The governance structure determines how information, standards, technologies and market requirements are communicated throughout the chain. In smallholder agricultural systems, effective value-chain coordination can facilitate access to markets, reduce transaction costs and improve product quality. Conversely, fragmented chains characterized by weak producer organization, poor infrastructure and limited market information can constrain value capture by producers.

Moringa as a Multipurpose Agricultural Commodity

Moringa is a highly versatile crop whose different plant parts can support multiple livelihood and commercial functions. Leaves can be consumed fresh or processed into powder, while seeds can be sold for food, planting material or oil extraction. The multipurpose nature of Moringa creates opportunities for product diversification and income generation. The commercialization of Moringa therefore extends beyond the sale of raw agricultural produce. Drying, milling, oil extraction, packaging and branding can transform relatively low-value raw materials into higher-value products. These transformations also provide opportunities for small and medium enterprises to participate in the agricultural economy. Kumssa et al. (2017) highlighted the growing importance of Moringa cultivation and utilization in Africa and emphasized its potential contribution to livelihoods and nutrition. However, realization of this potential depends on the development of functional markets, processing capacity and appropriate value-chain institutions.

Value Addition and Upgrading

Value addition involves transforming a product in ways that increase its economic or functional value. In agricultural systems, this may include cleaning, sorting, grading, drying, milling, extraction, packaging, labelling and branding. Such activities can improve quality, shelf life, convenience and marketability. Gereffi et al. (2005) identify product, process, functional and chain upgrading as important pathways through which actors can improve their position within value chains. For Moringa, processing fresh leaves into powder represents product upgrading, while adoption of improved drying or milling technologies represents process upgrading. Movement from raw-material production into processing and branding may constitute functional upgrading. Nevertheless, value addition requires capital, skills, equipment, reliable raw-material supplies, quality standards and market access. Without these supporting conditions, smallholder producers may remain concentrated in low-value activities while higher returns are captured further downstream.

Commercialization in Semi-Arid Agricultural Systems

Commercialization involves increasing the proportion of agricultural production directed towards markets and strengthening the ability of producers and other actors to participate in remunerative market systems. In semi-arid areas, commercialization may be particularly important because households face production risks and require diversified income sources. Market-oriented production can strengthen household income and encourage investment in processing and other value-chain activities. However, commercialization is constrained by poor roads, limited market information, inadequate storage, price fluctuations, weak bargaining power and restricted access to finance. For Moringa, these constraints may be compounded by the relatively underdeveloped nature of formal markets and processing enterprises. Strengthening market linkages and producer organizations can therefore contribute to more inclusive commercialization.

Conceptual Framework

The conceptual framework for this study views the Moringa value chain as an interconnected system comprising three broad dimensions. **First, value-chain structure** consists of the actors involved in production, aggregation, processing, wholesaling, retailing and consumption. **Second, value-chain functions** include cultivation, harvesting, aggregation, sorting, grading, drying, milling, oil extraction, packaging, transportation, marketing and consumption. **Third, value creation and upgrading** occur through transformation, product differentiation, improved quality, packaging, branding and stronger market coordination. The framework assumes that actor characteristics, access to resources, market relationships, infrastructure and institutional support influence the capacity of actors to perform value-chain functions. These factors, in turn, influence product flows, value addition and commercialization outcomes.

Materials And Methods

Study Area

The study was conducted in Kibwezi East and Kibwezi West Sub-Counties of Makueni County, Kenya. Four wards were purposively selected: Thange and Masongaleni in Kibwezi East, and Makindu and Emali in Kibwezi West. The study area is predominantly semi-arid and characterized by variable rainfall, recurrent moisture stress and mixed crop-livestock production. Moringa is cultivated as part of household livelihood diversification and is utilized for food, nutrition and income generation.

Research Design

A descriptive cross-sectional research design was adopted. The design was appropriate because the study sought to characterize the structure of the Moringa value chain, identify actors and their roles, examine product flows and describe value addition and commercialization patterns at a particular period.

Target Population and Sampling

The broader target population consisted of 3,682 Moringa value-chain actors. These included producers, brokers or middlemen, processors, wholesalers, retailers and consumers. A total of **650 respondents** were included in the final study. The sample was deliberately larger than the minimum sample required for a descriptive survey in order to obtain adequate representation of the different actor categories and the four study wards.

The respondents comprised:

Actor category	Frequency	Percentage
Producers	167	25.7
Middlemen/brokers	90	13.8
Retailers	108	16.6
Wholesalers	63	9.7
Processors	12	1.8
Consumers	210	32.3
Total	650	100.0

The ward distribution was 275 respondents (42.3%) in Makindu, 160 (24.6%) in Emali, 105 (16.2%) in Masongaleni and 110 (16.9%) in Thange.

Data Collection

Primary data were collected using structured questionnaires administered to the different categories of Moringa value-chain actors. The questionnaires captured socio-demographic characteristics, actor participation, functional roles, products handled, sources and destinations of products, processing activities, market relationships, production, sales and household consumption. Additional information was collected on value addition activities, prices, processing costs, market constraints, infrastructure and access to services supporting commercialization.

Data Processing and Analysis

Data were coded, entered and analysed using IBM SPSS Statistics version 26. Descriptive statistics, including frequencies, percentages and cross-tabulations, were used to summarize actor characteristics, product distribution and commercialization patterns. Chi-square tests were used to assess whether observed differences in selected categorical variables across the four wards were statistically significant. Statistical significance was evaluated at the 5% level. The study deliberately did not use the four-ward aggregated ordinary least squares model contained elsewhere in the thesis because the number of aggregated observations was too small to support robust inferential interpretation. Instead, Article 2 focuses on the larger actor-level dataset and descriptive value-chain evidence.

Value-Chain Mapping

Value-chain mapping was used to illustrate relationships among actors and the movement of products, information and financial resources. The mapping identified major stages from input supply and production through aggregation, processing, wholesaling and retailing to final consumption. Product flows were considered primarily downstream, while market information, prices, quality requirements and demand signals could move in both directions. Supporting institutions, including government agencies, extension services, research organizations, financial institutions and regulatory bodies, were considered part of the enabling environment.

Production, Sales and Household Consumption

Production, sales and household consumption were assessed using reported quantities of Moringa products produced during the reference period.

The proportion marketed was calculated as:

$$\text{Percentage marketed} = (\text{Quantity sold} / \text{Total quantity produced}) \times 100$$

The proportion retained for household consumption was calculated as:

$$\text{Percentage consumed} = (\text{Quantity consumed} / \text{Total quantity produced}) \times 100$$

These measures were used to assess the degree to which Moringa production was oriented towards commercial markets rather than household consumption.

Value Addition and Economic Returns

Value addition was assessed by comparing producer prices, processor selling prices and retail prices for major Moringa products.

Gross value added was expressed as:

Value Added = Retail Price – Producer Price

Net value added was calculated as:

Net Value Added = Value Added – Processing Cost

The analysis covered fresh leaves, dried leaf powder, seeds and seed oil. The principal value-addition activities identified included sorting, transportation, drying, milling, cleaning, grading, storage, oil extraction, packaging and branding.

Commercialization Constraints

Respondents were asked to identify factors constraining production, processing and commercialization. These included price levels and fluctuations, competition, processing facilities, technical skills, access to finance, transportation, storage, market information and linkages between producers and buyers.

Validity and Reliability

The questionnaire was developed from the study objectives and reviewed to ensure that the items adequately captured the major dimensions of the Moringa value chain. Pre-testing was undertaken before the main survey to identify ambiguities and improve the clarity and consistency of the instrument.

Ethical Considerations

Ethical procedures were observed throughout the study. Relevant institutional and administrative permissions were obtained before data collection. Respondents were informed of the purpose of the study, participation was voluntary, and confidentiality of information was maintained.

RESULTS

Socio-Demographic Characteristics of Value-Chain Actors

Women constituted the majority of respondents across the four wards. Female participation was 63.0% in Makindu, 62.0% in Emali, 62.3% in Masongaleni and 55.5% in Thange. Married respondents constituted the largest marital category, accounting for approximately half or more of respondents across the study wards.

Educational attainment was concentrated at primary and secondary levels. Primary education accounted for 51.7% of respondents in Makindu, 54.3% in Emali, 50.0% in Masongaleni and 52.1% in Thange. Secondary education accounted for 35.2%, 40.0%, 30.3% and 30.1%, respectively. Tertiary education represented a smaller proportion, ranging from 6.5% in Makindu to 12.3% in Masongaleni.

Farming was the principal occupation for most respondents, accounting for 85.7% in Makindu, 82.9% in Emali, 79.5% in Masongaleni and 82.2% in Thange.

Among Moringa-growing households, average household age ranged from 41.7 years in Emali to 46.9 years in Masongaleni, while average household size ranged between 5.3 and 5.9 persons. Mean farming experience ranged from approximately 17.5 to 21.1 years.

Average household landholding was approximately 2.23 ± 0.97 ha, while average cultivated land was approximately 1.74 ± 0.73 ha. Masongaleni had the largest average landholding, approximately 2.71 ± 1.13 ha, while Emali had the smallest, approximately 1.98 ± 0.81 ha.

Structure and Distribution of Moringa Value-Chain Actors

The Moringa value chain comprised producers, middlemen or brokers, wholesalers, processors,

retailers and consumers. The largest respondent category was consumers, representing 32.3% of the sample, followed by producers at 25.7%.

The distribution of some actor categories varied significantly between wards. Broker participation differed significantly across the four wards ($\chi^2 = 79.69$, $p < 0.001$). Retailer participation also differed significantly ($\chi^2 = 19.07$, $p < 0.001$), while processor participation showed significant spatial variation ($\chi^2 = 11.30$, $p = 0.010$).

In contrast, differences in producer participation were not statistically significant ($\chi^2 = 5.48$, $p = 0.140$), nor were differences in wholesaler participation ($\chi^2 = 5.01$, $p = 0.171$).

These results indicate that the basic production function was relatively widespread across the study area, while intermediary and processing functions were more spatially differentiated.

Functional Roles of Value-Chain Actors

Producers

Producers occupied the upstream end of the value chain and were responsible for land preparation, planting, crop management, harvesting and initial handling of Moringa products. They supplied fresh leaves, seeds and other products to household consumers, brokers, retailers and processors.

The producer function constituted the foundation of the value chain because the availability and quality of raw material determined the capacity of downstream actors to undertake processing and marketing.

Middlemen and Brokers

Middlemen or brokers aggregated Moringa products from producers and facilitated transactions between producers and downstream buyers. Their functions included collection, aggregation, price negotiation, transportation coordination and linking producers with processors, wholesalers and retailers.

The significant spatial variation in broker participation suggests that intermediary networks were particularly important in some wards where producers required market access beyond immediate local markets.

Processors

Processors performed higher-value functions including sorting, cleaning, drying, milling, oil extraction, packaging and, in some cases, branding. These activities transformed raw Moringa materials into products with higher market value and longer shelf life.

Processors represented only 1.8% of the total sample, indicating that processing remained a relatively specialized activity.

Wholesalers

Wholesalers aggregated larger volumes and redistributed products to retailers and other markets. Their activities helped connect local production areas with wider markets and enabled products to move in larger quantities.

Retailers

Retailers represented 16.6% of respondents and connected Moringa products to final consumers. Retailing occurred through local shops, markets and other outlets. Retailers were important in determining product availability and communicating consumer preferences back to upstream actors.

Consumers

Consumers represented 32.3% of respondents and constituted the final point in the product flow. Their preferences influenced demand for fresh leaves, seeds, dried products and seed oil. Factors such as price, perceived quality, convenience and product form were relevant to consumption decisions.

Moringa Products Marketed Across the Four Wards

Five major categories of Moringa products were identified: fresh leaves, seeds, dried leaves/leaf powder, flowers and seed oil.

Product	Makindu n (%)	Emali n (%)	Masongaleni n (%)	Thange n (%)	χ^2	p-value
Fresh leaves	100 (43.5)	54 (41.9)	46 (37.7)	50 (34.2)	8.37	0.039
Seeds	109 (47.4)	34 (26.4)	36 (29.5)	64 (43.8)	47.18	<0.001
Dried leaves	12 (5.2)	25 (19.4)	21 (17.2)	13 (8.9)	27.17	<0.001
Flowers	6 (2.6)	10 (7.8)	10 (8.2)	12 (8.2)	15.82	0.001
Seed oil	3 (1.3)	6 (4.7)	9 (7.4)	7 (4.8)	14.83	0.002

Percentages represent respondents reporting each product and therefore are not mutually exclusive.

Fresh leaves were widely marketed across all four wards, ranging from 34.2% in Thange to 43.5% in Makindu. Seeds were particularly important in Makindu and Thange. Dried leaves were more prevalent in Emali and Masongaleni than in Makindu and Thange.

Flowers and seed oil represented smaller but commercially important product categories. Seed oil was reported by 7.4% of respondents in Masongaleni compared with 1.3% in Makindu.

The statistically significant differences in the distribution of products indicate that the Moringa product portfolio was not uniform across the study area.

Value-Chain Mapping and Product Flows

The value-chain mapping demonstrated a largely linear but functionally interconnected system.

Input suppliers → Producers → Brokers/Aggregators → Processors/Wholesalers → Retailers → Consumers

Producers supplied raw Moringa products to brokers, local traders, retailers and processors. Brokers aggregated products and connected producers with larger buyers. Processors transformed leaves and seeds into higher-value products, particularly leaf powder and seed oil. Wholesalers redistributed products in bulk, while retailers connected products with final consumers.

Product flows were primarily downstream, while prices, market information, quality requirements and consumer demand moved upstream and between actors. Financial flows generally moved in the opposite direction to physical product flows, from consumers through retailers, wholesalers and processors to producers.

The chain was supported by institutional actors including government agencies, extension and research organizations, financial service providers and regulatory or quality-assurance institutions.

The mapping also showed that the chain was not equally developed at every stage. Production was relatively widespread, whereas processing capacity was limited and concentrated among a small number of actors.

Production, Sales and Household Consumption

Moringa production was strongly market oriented.

Ward	Production (kg)	Sold (kg)	Consumed (kg)	Sold (%)	Consumed (%)
Emali	22,631	16,580	6,054	73.3	26.7
Makindu	20,751	15,227	5,431	73.4	26.6
Masongaleni	21,754	16,040	5,729	73.7	26.3
Thange	19,526	14,111	5,273	72.3	27.0

Approximately 72.3–73.7% of reported Moringa production was sold, while approximately 26.3–27.0% was retained for household consumption.

Masongaleni recorded the highest proportion sold at 73.7%, while Thange recorded the lowest at 72.3%. The relatively small differences between wards indicate that Moringa production was predominantly commercial throughout the study area.

The results demonstrate that Moringa served both income-generation and household-consumption functions. The majority of production, however, was directed towards markets.

Value Addition and Economic Returns

Substantial differences were observed between raw Moringa products and processed products.

Table 2. Economic Value Addition of Major Moringa Products

Product	Ward	Producer price (KSh/kg)	Processing cost (KSh/kg)	Processor selling price (KSh/kg)	Retail price (KSh/kg)	Net value added (KSh/kg)	Main value-addition activity
Fresh leaves	Makindu	55	15	75	90	20	Sorting and transportation
Fresh leaves	Emali	60	18	80	95	17	Sorting and transportation
Fresh leaves	Masongaleni	58	17	78	93	18	Sorting and transportation
Fresh leaves	Thange	57	16	76	92	19	Sorting and transportation
Leaf powder	Makindu	55	145	220	500	300	Drying and milling

Leaf powder	Emali	60	170	280	650	420	Drying, milling and packaging
Leaf powder	Masongaleni	58	160	250	600	382	Drying and milling
Leaf powder	Thange	57	150	230	550	343	Drying and packaging
Seeds	Makindu	120	30	180	250	100	Cleaning and grading
Seeds	Emali	130	35	200	280	115	Cleaning and packaging
Seeds	Masongaleni	180	45	300	450	225	Cleaning and storage
Seeds	Thange	140	35	190	230	55	Cleaning and grading
Seed oil	Makindu	120	600	900	1,800	1,080	Oil extraction
Seed oil	Emali	130	650	1,100	2,000	1,220	Oil extraction and packaging
Seed oil	Masongaleni	180	700	1,400	2,500	1,620	Oil extraction, branding and packaging
Seed oil	Thange	140	620	1,000	1,900	1,140	Oil extraction and packing

Fresh leaves generated relatively low net value added, ranging from KSh 17/kg in Emali to KSh 20/kg in Makindu. Value addition was mainly limited to sorting and transportation.

Dried leaf powder generated considerably higher returns. Net value added ranged from KSh 300/kg in Makindu to KSh 420/kg in Emali. The major transformation activities were drying, milling and packaging.

Seed products also generated additional value. Net value added ranged from KSh 55/kg in Thange to KSh 225/kg in Masongaleni. Masongaleni recorded the highest seed price and the highest net value added, reflecting stronger aggregation, storage and market opportunities.

Seed oil recorded the highest net value added across all products, ranging from KSh 1,080/kg in Makindu to KSh 1,620/kg in Masongaleni. The higher returns were associated with oil extraction, packaging and, in Masongaleni, branding.

These findings demonstrate that the economic value of Moringa increases substantially as products move from raw materials towards processed and differentiated forms.

Constraints to Commercialization and Upgrading

Several constraints limited commercialization and value-chain upgrading.

The major constraints included low producer prices, price fluctuations, market competition, inadequate processing facilities, limited technical skills, inadequate access to finance, poor transport and storage infrastructure, limited market information and weak linkages between producers and buyers.

At the production level, pests and limited access to quality planting materials also constrained expansion of Moringa production.

These constraints were particularly important for small-scale producers and processors because value addition requires equipment, reliable raw-material supplies, technical knowledge, packaging materials and access to remunerative markets.

The limited number of processors in the sample further suggests that the transition from raw-material production to higher-value processing remains an important development gap.

DISCUSSION

Structure and Organization of the Moringa Value Chain

The study established that the Moringa value chain in semi-arid Makueni County consists of a network of specialized but interconnected actors. Producers formed the foundation of the chain, while brokers, wholesalers, processors and retailers facilitated the movement and transformation of products before they reached consumers.

This structure is consistent with value-chain theory, which emphasizes that agricultural commodities acquire value through a sequence of interconnected activities rather than through production alone (Kaplinsky & Morris, 2002). The presence of specialized intermediary and processing functions also demonstrates that Moringa commercialization has progressed beyond purely subsistence production.

However, the uneven distribution of actors across wards indicates that the chain is spatially differentiated. Significant differences in broker, retailer and processor participation suggest that market accessibility, infrastructure, production volumes and investment opportunities may influence where particular functions develop.

Functional Specialization and Opportunities for Upgrading

Functional specialization was evident throughout the chain. Producers concentrated on primary production, brokers on aggregation and market intermediation, processors on transformation, wholesalers on bulk distribution and retailers on final-market access.

While specialization can improve efficiency, it can also result in unequal value capture. Producers who sell primarily fresh leaves or raw seeds have fewer opportunities to capture value generated through drying, milling, extraction, packaging and branding.

The findings therefore point to functional upgrading as an important opportunity. Producer groups and cooperatives could move beyond collective production into aggregation, primary processing and packaging. Such upgrading could increase producer participation in downstream activities while reducing dependence on intermediaries.

Product Diversification and Commercialization

Fresh leaves and seeds were the most widely marketed products, indicating that the Moringa value chain remains substantially dependent on raw or minimally processed commodities. However, the presence of dried leaves, leaf powder and seed oil demonstrates emerging product diversification.

The spatial variation in product distribution is particularly important. Emali and Masongaleni showed stronger participation in dried products and seed oil than Makindu, suggesting differences in processing capacity and market integration.

Product diversification can reduce dependence on a single market and provide alternative outlets for Moringa biomass. It may also reduce the perishability associated with fresh leaves and extend the geographical range over which products can be marketed.

Production Orientation and Household Commercialization

The finding that approximately three-quarters of Moringa production was marketed indicates a strong commercial orientation. Only about one-quarter was retained for household consumption.

This pattern demonstrates that Moringa serves a dual livelihood function: it provides products for household use while simultaneously generating market income. The relatively high marketed proportion indicates that producers recognize the commodity's economic potential.

Commercial orientation is important in semi-arid agricultural systems because households require income diversification in response to production and climatic risks. However, commercialization alone does not guarantee improved livelihoods. The distribution of value between producers and downstream actors remains critical.

Value Addition as a Pathway to Higher Economic Returns

The strongest finding from the study is the substantial increase in economic value associated with processing.

Fresh leaves generated net value added of only KSh 17–20/kg, whereas leaf powder generated KSh 300–420/kg. Seed oil generated KSh 1,080–1,620/kg. These differences demonstrate the economic importance of transformation activities.

The results are consistent with the value-chain upgrading perspective of Gereffi et al. (2005), which emphasizes movement into higher-value functions as a pathway for increasing competitiveness and value capture.

The transformation of fresh leaves into powder provides an especially important example. Drying and milling reduce perishability and create a product that can be packaged and transported over longer distances. Similarly, seed oil extraction converts a relatively low-value raw material into a differentiated product with substantially higher market value.

The findings therefore support the argument that Moringa commercialization should not focus solely on increasing production volumes. Investment in processing and product differentiation is equally important.

Uneven Development of Higher-Value Processing

Despite the substantial returns associated with processing, only 12 respondents were processors. This indicates that higher-value activities remain concentrated among a relatively small group. Masongaleni recorded particularly high returns from seeds and seed oil, while Emali recorded the highest return from leaf powder. Such spatial differences suggest that local infrastructure, market relationships, access to equipment, entrepreneurship and availability of raw materials influence processing development.

The concentration of processing also raises concerns about inclusiveness. If producers cannot access processing technologies or organized markets, most of the additional value generated through transformation may be captured by downstream actors.

Constraints Limiting Commercialization and Upgrading

The identified constraints—low producer prices, price fluctuations, competition, inadequate processing facilities, limited technical skills, insufficient capital, poor transport and limited market information—represent interrelated barriers rather than isolated problems.

For example, inadequate finance limits the ability of processors to purchase equipment, while inadequate processing facilities constrain product diversification. Weak market information can reduce producers' bargaining power, while poor transport can increase transaction costs and reduce the competitiveness of products.

These findings emphasize the importance of addressing value-chain constraints as a system. Improving production alone will have limited impact if processors cannot access raw materials, traders lack market information, and producers lack reliable buyers.

Implications for Climate-Resilient Commercialization

The findings broaden the concept of climate resilience beyond farm-level production. A commercially viable Moringa system requires resilience across production, processing, storage, transportation and markets.

Processing can contribute to resilience by extending shelf life and reducing dependence on immediate sale of fresh leaves. Drying and milling can therefore help households and enterprises manage periods of weak market access or temporary disruptions.

Similarly, improved storage and aggregation can enable producers to coordinate supply with market demand rather than selling immediately after harvest.

Consequently, climate-resilient commercialization should combine production support with investment in post-harvest handling, decentralized processing, market infrastructure and institutional coordination.

Overall Contribution of the Study

The study provides an empirical description of the Moringa product value chain in a semi-arid Kenyan context. It demonstrates that the chain is no longer limited to direct producer-to-consumer transactions but includes specialized intermediary, processing and distribution functions.

More importantly, the findings show that substantial economic value is generated through processing, but access to these higher-value activities remains uneven. The key development challenge is therefore not simply increasing Moringa production, but enabling a broader range of actors, particularly producers and producer organizations to participate in value addition and capture a greater share of the resulting benefits.

CONCLUSION

The Moringa product value chain in Kibwezi East and West Sub-Counties is commercially active and comprises producers, brokers, processors, wholesalers, retailers and consumers connected through product, information and financial flows. Fresh leaves and seeds remain the dominant products, but dried leaf powder and seed oil demonstrate significant opportunities for product diversification and value-chain upgrading.

Approximately 72–74% of Moringa production was marketed, demonstrating a predominantly commercial orientation. However, the distribution of actors and value-chain functions varied across wards, particularly for brokers, retailers and processors.

The study established substantial differences in economic value between raw and processed products. Fresh leaves generated relatively low net value added, while leaf powder, seeds and particularly seed oil generated considerably higher returns. These findings demonstrate that value addition is a major pathway through which the Moringa value chain can generate greater economic value.

Nevertheless, limited processing capacity, inadequate finance, technical constraints, poor infrastructure, market information gaps and weak producer-buyer linkages restrict broader participation in higher-value activities.

The study concludes that sustainable commercialization of Moringa in semi-arid Makueni County requires a shift from production-oriented development towards integrated value-chain upgrading.

Policy And Practical Implications

First, county and national agricultural development programmes should support **decentralized Moringa processing facilities**, particularly for drying, milling and seed-oil extraction. Locally accessible facilities would reduce the costs associated with transporting raw products and allow producers to participate more directly in value addition.

Second, **producer organizations and cooperatives** should be strengthened to facilitate collective aggregation, processing, and purchasing of equipment and marketing. Collective action can improve bargaining power and reduce dependence on individual intermediaries.

Third, financial institutions and development programmes should develop **appropriate financing mechanisms** for small-scale Moringa processors and producer organizations. Access to affordable credit is particularly important for equipment, packaging and storage investments.

Fourth, county governments and private-sector actors should improve **market information systems** covering prices, demand, quality requirements and potential buyers. Timely market information can strengthen negotiation capacity and reduce information asymmetries.

Fifth, training programmes should focus on **post-harvest handling, drying, milling, oil extraction, hygiene, packaging, branding and quality management**. Such skills are essential for enabling actors to enter higher-value markets.

Sixth, investments in **rural roads, storage and market infrastructure** should be integrated into Moringa commercialization strategies. Poor transport and storage infrastructure can undermine the benefits generated through production and processing.

Finally, standards, certification and product-quality systems should be strengthened to support access to formal domestic and potentially regional markets. Product safety, consistent quality, packaging and traceability will become increasingly important as the Moringa industry develops.

LIMITATIONS AND AREAS FOR FURTHER RESEARCH

The study was cross-sectional and therefore captured the Moringa value chain during a particular period. Longitudinal studies would be useful for examining how climate variability, prices and market demand influence value-chain participation over time.

Further research should examine gender and youth participation in higher-value processing activities, since participation in different value-chain functions may not be equally distributed across demographic groups.

Future studies should also examine the feasibility of certification, branding and formal-market development for Moringa products. Comparative economic studies across semi-arid counties could further establish how differences in infrastructure, climate, market access and institutional support influence value-chain performance.

DECLARATIONS

Ethical Approval

The study was conducted following the relevant institutional and administrative ethical requirements. Participation was voluntary and respondents were informed about the purpose of the study.

Consent to Participate

Informed participation was obtained from respondents before administration of the questionnaires.

Conflict of Interest

The authors declare that they have no conflict of interest relating to this study.

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