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Original Article

Beyond Milk Marketing: Dairy Cooperatives as Comprehensive Technology Intermediaries in Smallholder Value Chains - Evidence from Uasin Gishu County, Kenya

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Abstract

Agricultural cooperatives in East African dairy systems have evolved well beyond their original mandate as collective marketing organisations. This study examines cooperatives as comprehensive technology intermediaries, simultaneously functioning as technology gateways, training providers, market linkage mechanisms, financial access bridges, gender inclusion institutions, and social norm anchors in the Uasin Gishu County dairy sector of Kenya. Using a concurrent mixed-methods design comprising a quantitative survey of 355 dairy value chain actors across three sub-counties, Ainabkoi, Kapseret, and Moiben, and seven Key Informant Interviews with four cooperative managers and three county livestock officers, the study examined the comprehensive technology-intermediary functions of dairy cooperatives. Cooperative membership is 79.7%, with members rating service effectiveness at M = 3.924 (SD = 1.070) and service utilisation at M = 4.194 (SD = 0.965). The cooperative is the primary technology access channel, cited by 71.8% of respondents; 16.3 percentage points ahead of the Ministry of Agriculture. Crucially, membership uniquely predicts Technology Use Level with a large effect size (Members M = 3.636 vs. Non-members M = 2.772; $t = 6.352$, $p < 0.001$; Cohen's $d = 0.763$) while no capital construct (Human, Financial, Social, Natural, Physical, Cultural, or Political) differs significantly by membership status. This finding establishes the cooperative's effect as institutional rather than material: cooperatives create adoption-enabling conditions that are not reducible to the capital stocks they transfer. Members also report better economic outcomes: production gains ≥10% (68.5% vs. 56.1%), cost reduction (74.4% vs. 57.9%, $p = 0.019$), and income increase (79.1% vs. 56.9%, $p = 0.001$). Qualitative evidence reveals a three-tier progressive adoption programming model (60% basic, 30% mid-level, 10% advanced), a gender-inclusive joint household training model that produced near gender parity (53:47 male:female) and 200% milk volume growth over two years, and a competitive intelligence function that protects members against large-processor market predation. The paper argues for cooperative institutional quality (not merely cooperative existence) as the central determinant of dairy technology adoption at the system level, and identifies cooperative-centred extension, joint training mandates, and cooperative protection policy as the three highest-priority interventions for county government and development partners.

Categories: Agricultural and food economics, Agricultural technology (machinery, remote sensing), Food security and sustainability

Keywords: dairy cooperatives, technology intermediaries, smallholder agriculture, kenya, social capital, extension services, technology adoption, gender inclusion, value chain

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Introduction

Agricultural cooperatives were initially organised to facilitate collective marketing, strengthen producers' bargaining position, and reduce the transaction costs faced by individual farmers. By aggregating produce and coordinating exchanges, they helped smallholders overcome difficulties associated with limited market information, low output volumes, weak negotiating power, and costly individual transactions [1-8]. Across many African agricultural systems, however, cooperative functions have expanded beyond their traditional marketing mandate. Cooperatives increasingly provide or coordinate input access, extension linkages, farmer training, market information, quality assurance, financial services, and connections with research institutions, public agencies, processors, and private service providers. This development has repositioned some cooperatives as rural service institutions rather than organisations concerned solely with the sale of members' produce.

Evidence from several agricultural settings supports this broader institutional role, although cooperative outcomes differ across commodities, locations, and organisational arrangements. Studies in Kenya, Ethiopia, Rwanda, Nigeria, China, India, and other smallholder systems have associated cooperative participation with improved information flows, access to inputs and extension, agricultural technology adoption, technical efficiency, market participation, income, asset accumulation, and household welfare [9-18]. Kenyan dairy-hub evidence has also linked collective participation with access to services, milk yields, and net farm returns [19]. More recent Kenyan research has connected cooperative membership with technical efficiency and the adoption of sustainable dairy practices, while also identifying information, governance, and organisational constraints which limit the benefits available to members [20]. These findings indicate that cooperative performance should not be assessed only through prices or collective sales. It also depends on the range, quality, accessibility, and continuity of services surrounding production and technology use.

Technology adoption in smallholder dairy systems is particularly dependent on coordinated support. Dairy technologies often require complementary changes in feeding, breeding, animal health, housing, hygiene, milk handling, record-keeping, energy use, waste management, input procurement, and marketing. Awareness of an innovation is therefore insufficient when farmers lack practical instruction, suitable inputs, finance, reliable service providers, or markets which reward improvements in productivity and quality [21,22]. Training also needs to be practical and relevant to farmers' production conditions because information without demonstration and technical follow-up might not result in regular use [23]. Research on Kenyan dairy systems has documented considerable variation in the adoption of technical, organisational, and institutional innovations [24]. Recent evidence from Meru County further shows that decisions to adopt different dairy technologies are interrelated and are influenced by factors including extension contact, credit access, group membership, education, income, and farming experience [25]. Research from Murang'a County similarly indicates that combinations of production, financial, business-development, and cooperative services produce different productivity and income outcomes [26]. These findings support an integrated approach in which dairy technology engagement depends on complementary services rather than isolated information campaigns.

Three theoretical perspectives help explain how cooperatives contribute to this process. Transaction cost theory and the new institutional economics draw attention to the costs farmers incur when searching for technologies, assessing input quality, negotiating with providers, obtaining credit, monitoring market conditions, and enforcing agreements [4-6]. Collective institutions reduce some of these costs by coordinating transactions, sharing information, and representing groups of producers. Ostrom's collective-action perspective further explains how shared rules and institutional arrangements support cooperation in situations where individual action is costly or ineffective [7]. Diffusion of Innovations theory presents adoption as a process involving knowledge, persuasion, decision, implementation, and confirmation rather than as a single choice following initial awareness [27]. Cooperatives potentially support different stages of this process through training, demonstrations, access to inputs, opportunities for trial, technical follow-up, quality monitoring, and links with dependable markets.

Social capital provides a related explanation for how cooperative membership influences technology engagement. Trust, shared expectations, repeated interaction, and social networks facilitate collective action and information exchange [28-30]. Within cooperatives, bonding relationships among family members, friends, neighbours, and other producers

operate alongside bridging relationships connecting members with extension officers, researchers, financial organisations, commercial suppliers, and processors. Agricultural technology studies have shown that farmers' adoption decisions are influenced by the experiences and choices of people within their information networks [31]. Farmers also adjust practices after observing the performance of technologies used by trusted peers [32]. Evidence from Ethiopia further suggests that extension agents and neighbouring farmers influence adoption at different stages, with peer learning becoming increasingly important as local experience accumulates [33]. Formal extension and social learning should therefore be understood as complementary rather than competing channels [22]. Cooperatives provide an institutional setting in which technical advice, practical observation, and peer discussion occur together.

Recent developments have made this coordinating role more important. Dairy farmers now encounter a wider range of digital, biological, mechanical, organisational, and environmentally oriented innovations. Digital farm-management systems, market platforms, electronic records, precision-feeding tools, improved breeding services, renewable-energy technologies, and climate-related production practices often require new skills, infrastructure, finance, data access, and sustained technical support. The growing complexity of these technologies increases the risk of fragmented adoption, where farmers become aware of an innovation but lack the complementary services required to use it effectively. Current agrifood research therefore places increasing emphasis on bundles of technological, institutional, social, and policy innovations rather than on isolated technical interventions [34]. Rapid food-system transformation has also increased the involvement of processors, retailers, logistics providers, digital platforms, and specialised service companies in agricultural value chains [35]. Recent Kenyan dairy evidence reinforces the importance of coordinated innovation services, especially where technology choices are interdependent and sustainable practices require links between farmers, cooperatives, project organisations, information systems, and emerging environmental markets [24-26,20].

Gender inclusion is another important concern within cooperative service delivery. Women make substantial contributions to livestock care, feeding, milking, hygiene, record-keeping, processing, and household dairy management. Nevertheless, women and men often experience different levels of access to land, finance, extension, training, technology, markets, and decision-making authority [36-40]. Treating the household as a single production and decision-making unit can conceal differences in who performs dairy work, who attends cooperative meetings, who receives technical information, who decides whether a technology is purchased, and who controls the income generated. Gender-responsive cooperative programming therefore requires more than increasing the number of female members. It also requires attention to training participation, leadership, direct access to technical information, technology decision-making, labour responsibilities, and economic benefits. These concerns are especially relevant where men attend formal training while women carry out much of the routine work through which recommended practices are implemented. FAO's recent assessment of women in agrifood systems confirms that inequalities in access to resources, services, technologies, finance, employment, and decision-making continue to shape women's opportunities and benefits throughout agrifood value chains [38].

Cooperatives also operate within markets characterised by changing prices, quality requirements, processor competition, and uneven bargaining power. Collective marketing helps smallholders aggregate output, reduce individual marketing costs, share price information, and negotiate with buyers [1,8,17]. However, these advantages depend on member participation, reliable delivery volumes, sound governance, timely payments, transparent records, and the cooperative's capacity to maintain services. When members divert produce to alternative buyers during periods of price competition, declining volumes might weaken collective bargaining and reduce the resources available for training, extension support, input facilitation, and credit arrangements. At the same time, farmers have legitimate reasons to seek buyers offering better prices or payment conditions. Cooperative responses must therefore focus on service quality, transparency, organisational credibility, market diversification, and stable member relations rather than on restricting farmers' market choices. Wider food-system research also indicates that technological innovation alone is insufficient when market, policy, governance, and sociocultural conditions remain poorly aligned [34,35].

Despite the breadth of existing research, important gaps remain. Previous studies have examined cooperative membership in relation to commercialisation, input use, technical efficiency, technology adoption, dairy performance, income, welfare, and market participation [1,9-19,21]. Other studies have considered dairy innovation patterns,

interdependent adoption choices, combinations of agribusiness support services, and cooperative roles in sustainable production [20,24-26]. Most of this evidence, however, concentrates on individual outcomes or selected cooperative functions. Less attention has been given to how training, extension, input access, market information, peer networks, financial services, quality support, and market coordination operate together within one dairy technology-support system.

A further gap concerns the source of membership-related differences. Higher technology use among cooperative members might reflect greater access to livelihood resources, including human, financial, physical, natural, social, cultural, and political capital. Alternatively, it might arise from the institutional environment created through coordinated services, repeated training, peer interaction, technical follow-up, and market support. Distinguishing between these explanations has practical significance. Where differences arise mainly from unequal resource endowments, policy responses should prioritise access to assets and finance. Where differences arise primarily from institutional coordination, attention should shift towards the quality, continuity, and inclusiveness of cooperative and extension services. Existing studies provide limited evidence comparing these explanations while examining technology use, suitability, awareness, economic outcomes, barriers, and adoption intentions within the same dairy value chain.

Uasin Gishu County provides an appropriate setting for addressing these questions. The county includes Ainabkoi, Kapseret, and Moiben among its administrative sub-counties [41], and its dairy value chain brings together farmers, cooperatives, public extension agencies, research and training organisations, agro-dealers, processors, and other service providers. Variation in cooperative participation and technology engagement across the selected study areas provides an opportunity to examine how dairy actors access technologies and how members and non-members differ in their reported experiences. The setting also permits examination of differentiated farmer support, household training, gender inclusion, and cooperative responses to reported market pressures.

This study examined the role of dairy cooperatives as comprehensive technology intermediaries among dairy value-chain actors in Uasin Gishu County, Kenya. Specifically, it characterised the institutional services provided by cooperatives and identified the channels through which respondents accessed dairy technologies. It compared cooperative members and non-members in relation to Technology Use Level, perceived Technology Suitability, seven livelihood capital constructs, adoption barriers, Economic Impact, technology awareness, and Adoption Intention. It also examined membership-related differences in reported production, cost, and income outcomes. Qualitative accounts were used to explore differentiated technology-support programming, joint household training, gender inclusion, and cooperative responses to reported market pressures. By examining these dimensions together, the study contributes to cooperative and technology-adoption research by assessing whether membership-related differences reflect livelihood resource endowments or the institutional coordination of information, training, services, peer learning, and market support.

Materials And Methods

Study context

The study was conducted in Uasin Gishu County in Kenya's North Rift region. Agriculture is a major economic activity within the county, and dairy production is supported by public extension services, cooperative societies, research and training institutions, input suppliers, processors, and other private service providers (Figure *1*) [41].

Ainabkoi, Kapseret, and Moiben sub-counties were selected purposively to capture variation in agroecological conditions, market access, infrastructure, and dairy production systems. The achieved sample comprised 130 respondents from Ainabkoi, 90 from Kapseret, and 135 from Moiben. Differences in cooperative membership, Technology Use Level, and livelihood-capital scores across the sub-counties were examined after data collection and are therefore presented in the Results and Discussion section rather than as criteria for site selection.

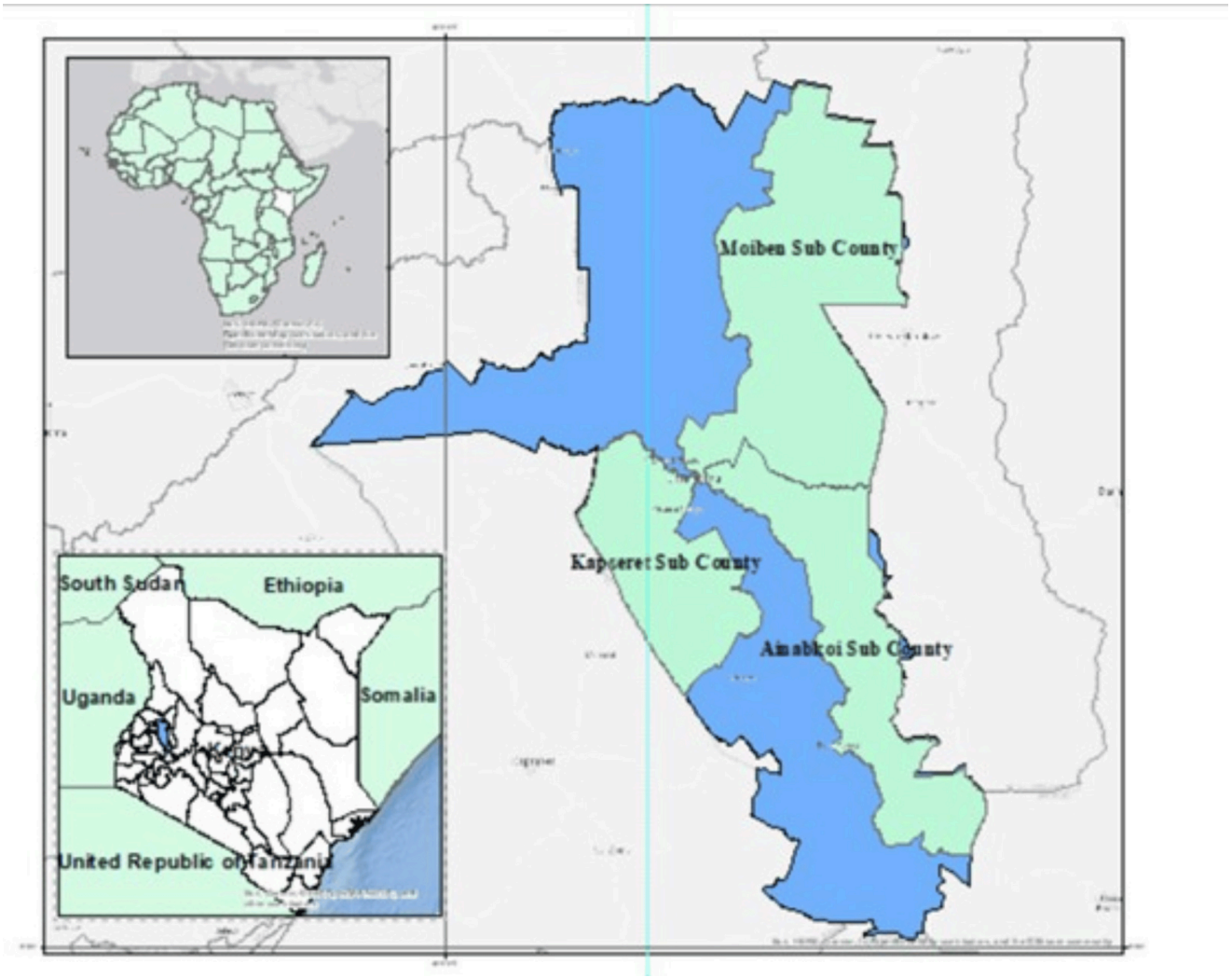


FIGURE 1: Map of Uasin Gishu

Study design and data collection

The study employed a convergent mixed-methods design in which quantitative survey data and qualitative Key Informant Interview data were collected during the same study period, analysed separately, and integrated during interpretation [42]. Data collection took place from August to November 2025.

The target population comprised 5,115 dairy value-chain actors across the three selected sub-counties. Using Yamane's finite-population formula at a 5% margin of error, the planned quantitative sample was 371 respondents [43]. A total of 355 fully completed questionnaires were obtained, representing 95.7% of the planned sample.

Stratified proportional random sampling was used for the quantitative survey. The population was stratified first by sub-county and then by dairy value-chain category. Respondents were selected through simple random sampling from cooperative membership lists, agricultural extension household registers, and dairy-farmer association rosters. Where complete lists were unavailable, systematic sampling was applied within the identified dairy-production areas. The resulting sample comprised 130 respondents from Ainabkoi, 90 from Kapseret, and 135 from Moiben.

The structured questionnaire contained sections covering respondents' socioeconomic and farm characteristics, seven livelihood-capital constructs, technology awareness, Technology Use Level, perceived Technology Suitability, adoption barriers, information sources, perceived Economic Impact, and Adoption Intention. Items used five-point response

formats with anchors appropriate to the type of question, ranging from 1 to 5. The questionnaire was pre-tested with 30 dairy farmers who were excluded from the main sample. The pilot instrument recorded an overall Cronbach's alpha of 0.78. Trained enumerators administered the questionnaire in English or Kiswahili using standardised procedures.

Qualitative data were obtained through seven Key Informant Interviews involving four cooperative society managers and three county livestock officers. The managers represented both long-established and recently established cooperatives, allowing differences in institutional experience and organisational development to be examined. Participants were selected purposively because of their institutional knowledge and strategic positions within the dairy value chain. Snowball referrals assisted in identifying additional information-rich participants.

The interviews were conducted in English or Kiswahili, audio-recorded with participants' permission, transcribed verbatim, and translated where required. Summary interpretations were returned to the informants for verification. Quantitative and qualitative evidence was integrated through a weaving approach in the Results and Discussion section, where interview accounts were used to explain and contextualise the survey patterns.

Quantitative measures

Cooperative membership was measured as a binary variable coded as member or non-member. Cooperative services were assessed through separate five-point items measuring overall service effectiveness, service utilisation, input supply through cooperatives, input purchases through cooperatives, and cooperative leadership engagement. Social-network integration was assessed through two items measuring the involvement of family members and friends in cooperative societies.

Five cooperative enabling functions were assessed separately: extension and technology support, market linkage and price information, training and skills development, financial services and credit access, and input-supply facilitation.

Technology-access channels were measured through a multiple-response item which allowed respondents to select more than one source. Awareness of each dairy technology was recorded separately. Technology Use Level ($\alpha = 0.899$), perceived Economic Impact ($\alpha = 0.788$), Adoption Intention ($\alpha = 0.845$), and perceived Technology Suitability ($\alpha = 0.855$) were measured using multi-item constructs. Construct scores were calculated as the mean of the relevant items, with higher scores representing higher levels of the measured construct.

Seven livelihood-capital constructs were included in the member and non-member comparisons: Financial, Physical, Human, Natural, Social, Cultural, and Political Capital. These constructs were treated as comparison variables rather than statistical controls.

Quantitative analysis

Quantitative analyses were conducted in Python 3.10 using NumPy, SciPy, and Pandas.

Differences between cooperative members and non-members on continuous constructs were examined using independent samples t tests. Distributional characteristics were examined before analysis, and equality of variances was assessed using Levene's test. Welch's t test was applied where the assumption of equal variances was not supported. Cohen's d was reported as the effect size measure, with values of approximately 0.20, 0.50, and 0.80 interpreted as small, moderate, and large, respectively [44].

Differences in categorical outcomes were examined using chi-square tests of independence. Expected cell frequencies were examined before the results were interpreted. Cramér's V was calculated to describe the strength of associations between categorical variables. Technology awareness differences were summarised as percentage point gaps between cooperative members and non-members. No inferential tests were conducted for the awareness comparisons, and these findings were therefore interpreted descriptively. Sub county variation in cooperative participation and technology outcomes was also described without causal interpretation.

Analyses used available cases for each statistical test. Respondents with missing observations on variables required for a particular analysis were excluded only from that analysis. No missing values were imputed. The valid sample size was reported for each statistical comparison.

Statistical significance was assessed at $\alpha = 0.05$. Results with $p \geq 0.05$ were treated as non-significant. Exact p values, test statistics, valid sample sizes, and effect sizes were reported where applicable.

Qualitative analysis

The interview data were analysed using a hybrid deductive and inductive codebook thematic approach guided by Braun and Clarke's six phase framework for thematic analysis [45]. Initial codes were developed from the study objectives and the conceptual perspectives presented in the Introduction section. Additional codes were generated inductively from recurring patterns identified during repeated reading of the interview transcripts.

The analysis involved familiarisation with the data, generation of initial codes, development of candidate themes, review and refinement of themes, definition and naming of themes, and preparation of the final report. A second researcher independently coded 20% of the transcript material, producing a Cohen's kappa coefficient of 0.81, which indicated strong agreement between coders. Coding discrepancies were resolved through discussion before the final thematic framework was established.

Qualitative findings were integrated with the quantitative results during interpretation to explain institutional practices, provide contextual understanding of the observed quantitative patterns, and identify potential mechanisms through which cooperatives supported technology adoption. The qualitative evidence was used to illustrate participants' experiences and institutional processes rather than to estimate the prevalence of views or practices across dairy cooperatives or value chain actors.

Ethical considerations

Ethical approval was obtained from the University of Eldoret Institutional Ethics Review Committee. A research permit was issued by the National Commission for Science, Technology and Innovation. Permission was also obtained from the relevant county authorities and participating cooperative societies.

Participants received information about the study's purpose, procedures, voluntary nature, confidentiality arrangements, and their right to withdraw. Informed consent was obtained before participation. Names and other identifying information were excluded from the survey dataset, interview transcripts, and manuscript quotations.

Results And Discussion

Cooperative institutional profile

Table *1* presents the cooperative institutional profile of the study participants. Of the 355 respondents, 283, representing 79.7%, were cooperative members, while 72, representing 20.3%, were non-members. Men accounted for 57.6% of cooperative members and women for 42.4%. Participation was therefore substantial among both groups, although male membership remained higher.

Respondents reported generally favourable experiences with cooperative services. Overall service effectiveness recorded a mean score of 3.924 (SD = 1.070), with 63.7% of respondents assigning a rating of 4 or 5. Service utilisation received a higher mean score of 4.194 (SD = 0.965), with 75.5% assigning ratings of at least 4. Input supply through cooperatives was rated at M = 4.115 (SD = 1.053), while purchases of inputs through cooperatives recorded M = 4.059 (SD = 1.097).

Characteristic	Statistic	Source/note
Membership and scale		

Cooperative members	283 (79.7% of sample)	Survey N = 355
Non-members	72 (20.3% of sample)	Survey N = 355
Gender composition of members	57.6% male, 42.4% female	Survey
Service ratings (1 = very poor, 5 = very good)		
Overall service effectiveness (COOP_SER_EFF)	3.924±1.070; 63.7% rated ≥4	Survey N = 355
Service utilisation frequency (COOP_SER_USE)	4.194±0.965; 75.5% rated ≥4	Survey N = 355
Input supply from cooperative	4.115±1.053; 78.0% rated ≥4	Survey N = 355
Input purchases from cooperative	4.059±1.097; 70.1% rated ≥4	Survey N = 355
Social network integration (1 = very low, 5 = very high)		
Family members in cooperative (FAM_COOP_MEM)	4.228±0.966; 84.2% rated ≥4	Survey N = 355
Friends in cooperative (FRD_COOP_MEM)	4.208±0.877; 81.4% rated ≥4	Survey N = 355
Cooperative leadership engagement (COOP_CTRL)	3.656±1.200; 58.6% rated ≥4	Survey N = 355
Enabler function ratings — STATE_II scale (1 = very ineffective, 5 = very effective)		
Extension and technology support	4.445±0.762	Survey N = 355
Market linkage and price information	4.437±0.815	Survey N = 355
Training and skills development	4.341±0.813	Survey N = 355
Financial services/credit access	3.620±1.207	Survey N = 355
Input supply facilitation	3.592±1.302	Survey N = 355
Word-of-mouth recommendation		
Recommend cooperative to others (WOM_TR)	265 (74.6%) yes	Survey N = 355

TABLE 1: Cooperative institutional profile, service ratings, social network integration, and enabling functions

Note: All items rated on a five-point Likert scale (1 = very poor/never/strongly disagree to 5 = very good/always/strongly agree). STATE_II items measure the effectiveness of each institutional function as perceived by respondents. Source: Primary survey data, Uasin Gishu County (2025)

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These ratings indicate that cooperative engagement extended beyond milk collection and marketing to include services directly relevant to production. This finding is consistent with evidence from Kenya and other African agricultural settings showing that producer organisations can reduce transaction and coordination constraints by combining collective marketing with access to productive services [1,13,18,19]. In the present study, the concentration of several services within the cooperative provides evidence of an intermediary function through which respondents accessed technical and commercial support without relying exclusively on separate individual transactions.

Social network integration also featured strongly in the institutional profile. The presence of family members in the cooperative recorded M = 4.228 (SD = 0.966), with 84.2% of respondents assigning ratings of at least 4. The corresponding score for friends in the cooperative was M = 4.208 (SD = 0.877), with 81.4% assigning ratings of at least 4. Cooperative leadership engagement received a lower mean score of 3.656 (SD = 1.200), although 58.6% still rated it at 4 or 5.

The strong family and friendship networks suggest that cooperative participation was embedded within existing social relationships. Such networks have relevance for technology engagement because farmers often obtain practical information by observing and discussing the experiences of peers operating under comparable conditions. Evidence from Mozambique, Ghana, and Ethiopia demonstrates the importance of social learning and farmer networks in technology decisions [31-33]. The cooperative setting potentially strengthens this process by bringing repeated interactions, technical information, and farmers' experiences into the same institutional environment. The lower rating for leadership engagement points to a different aspect of cooperative functioning. While member-to-member connections appeared strong, communication between members and management was less highly rated. This distinction suggests that social connectedness within a cooperative does not necessarily translate into equally strong upward communication or participation in organisational decision-making.

The ratings for specific cooperative functions further demonstrate variation in institutional capacity. Extension and technology support received the highest mean score at 4.445 (SD = 0.762), followed by market linkage and price information at 4.437 (SD = 0.815) and training and skills development at 4.341 (SD = 0.813). Financial services and credit access received a lower mean score of 3.620 (SD = 1.207), while input supply facilitation recorded the lowest score at 3.592 (SD = 1.302). The KII accounts showed a similar pattern, with managers describing training, technical support, and market linkage as relatively established functions, while financial services were constrained by limited cooperative capital. The convergence between the survey and interview evidence indicates that the cooperative's intermediary role was stronger in information, technical support, and market coordination than in financial intermediation.

This uneven pattern is important for understanding technology adoption. Extension and training support farmers in acquiring knowledge and practical skills, while market information provides an incentive for investment in improved production and quality. However, the transition from knowledge to actual technology use also depends on access to complementary inputs, equipment, and finance. The lower ratings for input facilitation and credit therefore suggest a potential institutional constraint at the implementation stage. This interpretation is consistent with evidence showing that agricultural technology decisions are shaped by combinations of extension, finance, market access, group participation, and other complementary services rather than awareness alone [20,24-26]. The present findings extend this perspective to the cooperative setting by showing how strengths and weaknesses within the same institution might occur at different points along the technology-support process.

The practical implication is therefore less about expanding the number of cooperative services than about improving the connections between them. Strong extension and training services need to be supported by reliable input channels, appropriate financial arrangements, technical follow-up, and market information. Cooperative leaders could strengthen these links through partnerships with financial institutions, input suppliers, research organisations, county extension services, and private technology providers. Such coordination would help members move from exposure to technologies towards practical trial and sustained use, while reducing dependence on the cooperative's own financial capacity for services it is less equipped to provide.

Finally, 265 respondents, representing 74.6% of the sample, reported that they would recommend their cooperative to others. This finding is consistent with the generally favourable ratings for service effectiveness and utilisation, although recommendation does not measure satisfaction with every service or continued participation under changing market conditions. Overall, the institutional profile indicates that the cooperatives in the study area operated across several functions relevant to technology engagement. Their strongest reported functions involved extension, technical support, training, market linkage, and information, while financial services, input facilitation, and leadership engagement received comparatively lower ratings. This variation provides an important basis for interpreting the subsequent findings on technology access and membership-related differences.

Technology access channels

Figure *2* presents the channels through which respondents accessed dairy technologies. Cooperative societies were the most frequently reported channel, cited by 255 respondents, representing 71.8% of the sample. The Ministry of Agriculture followed at 55.5%, while markets or agro-dealers were cited by 31.5%, research institutions by 29.9%, respondents' own farm experimentation by 29.3%, and farmer training schools by 21.7%. Since respondents selected more than one option, these channels represent complementary sources of technology access rather than mutually exclusive alternatives.

The prominence of cooperative societies confirms their importance as local points of contact between dairy value-chain actors and technology-related services. Previous section showed that respondents also linked cooperatives with extension support, training, input access, market information, and quality assurance. Considered together, the findings indicate that cooperatives connected several components of technology access within one institutional setting rather than serving only as information outlets.

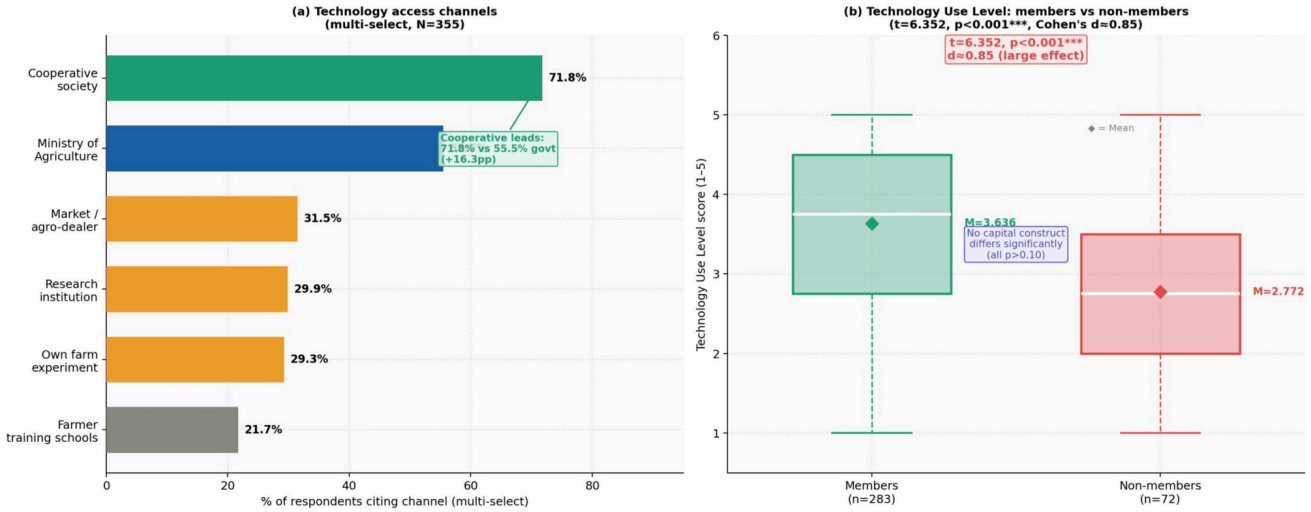


FIGURE 2: Technology access channels and the membership advantage in Technology Use

This is consistent with evidence from agricultural producer organisations showing that collective institutions can facilitate access to markets, productive services, technical information, and technologies by reducing some of the coordination difficulties faced by individual producers [1,13,18,19]. In the present study, the cooperative therefore appears to have functioned as a connecting institution rather than as a single source of technical information. From a transaction-cost perspective, cooperatives reduce the need for individual farmers to identify, approach, and negotiate with several providers separately [4-7]. They also create an organised setting in which technical information is explained, demonstrated, discussed, and assessed through interaction among members. Formal service delivery therefore operates alongside peer learning and practical observation.

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The Ministry of Agriculture remained an important technology-access channel, reaching 55.5% of respondents. This indicates that public extension continued to operate alongside cooperative structures. Research institutions, farmer training schools, markets, agro-dealers, and farm-level experimentation provided additional routes through which respondents encountered or assessed technologies. These channels performed different functions. Research institutions contributed technical knowledge and validation, commercial suppliers provided access to inputs and equipment, training schools supported skills development, and farm-level experimentation allowed respondents to assess technologies under their own production conditions. The coexistence of these channels indicates that technology access in the study area depended on several interacting institutional and farmer-level sources.

The distribution of access channels also fits the multi-stage process of technology engagement described by Diffusion of Innovations theory [27]. Initial awareness, practical assessment, trial, and continued use need not depend on the same information source. Evidence from agricultural technology studies similarly indicates that extension agents, neighbouring farmers, and social networks contribute differently to farmers' learning and technology decisions [31-33]. The present findings add a cooperative dimension to this process because the cooperative provided a setting where information from external providers could be combined with member interaction and practical experience. This helps explain why cooperative societies were reported more frequently than any other individual access channel.

The qualitative evidence provides further context for this intermediary function. One cooperative manager reported that members approached the cooperative for assistance with production inputs, household financial needs, and engagement with government agencies. This account represents the experience reported by KII-01 and does not establish how widely the same pattern occurred across cooperatives. It nevertheless illustrates how a cooperative could serve as a local access point through which farmers connected with government departments and other service providers. The interview evidence therefore complements the survey finding by showing one mechanism through which the cooperative's intermediary role operated in practice.

Sub-county patterns provided additional descriptive context. Cooperative membership was highest in Ainabkoi at 90.8%, followed by Kapseret at 77.8% and Moiben at 70.4%. Technology Use Level followed a similar descriptive pattern, with Ainabkoi recording M = 3.705, Kapseret M = 3.581, and Moiben M = 3.145. The correspondence between cooperative participation and technology engagement is consistent with an association between the two measures across the study sites. It does not establish a causal relationship because the comparison did not control for differences in farm characteristics, household resources, infrastructure, production conditions, or availability of other services.

The findings have implications for dairy extension planning. Cooperative societies provide a widely used route through which public agencies, researchers, training institutions, and technology suppliers reach dairy actors. Their role is best understood as complementary to public extension, farmer training schools, commercial suppliers, and farmer-led experimentation. Coordination among these actors would help maintain continuity between technology awareness, practical demonstration, trial, technical follow-up, and regular use. This is particularly relevant where different institutions provide different components of the technology-support process.

Cooperative membership and technology-related outcomes

Table *2* compares cooperative members and non-members across technology-related outcomes, livelihood capitals, and perceived adoption barriers. Cooperative members reported a higher Technology Use Level, M = 3.636, SD = 0.936, than non-members, M = 2.772, SD = 1.298. The difference was statistically significant, $t = 6.352$, $p < 0.001$, with a moderate-to-large effect size, Cohen's $d = 0.763$ [44]. This represented the largest difference between the two groups among the constructs examined.

Technology Suitability was also higher among members, M = 4.278, SD = 0.651, than among non-members, M = 4.067, SD = 0.742. The difference was statistically significant, $t = 2.362$, $p = 0.019$, although the effect size was small, $d = 0.303$. Cooperative membership was therefore associated with both greater technology use and a more favourable assessment of how well available technologies fitted respondents' production conditions.

Construct	Members n = 283	Non-members n = 72	t	p	Sig.	Cohen's d	Interpretation
Primary outcome of interest							
Technology Use Level (TU)	3.636±0.936	2.772±1.298	6.352	<0.001	***	0.763	Large-primary finding
Secondary outcomes							
Technology Suitability (TS)	4.278±0.651	4.067 ±0.742	2.362	0.019	*	0.303	Small-moderate
Economic Impact (EI)	3.040±0.837	2.792±1.015	1.953	0.052	†	0.266	ns
Adoption Intention (AI)	3.826±0.796	3.688±0.668	1.335	0.183	ns	0.187	ns
Livelihood capital comparisons							
Human Capital (HC)	M = 3.384	M = 3.246	1.458	0.146	ns	0.198	ns
Financial Capital (FC)	M = 3.028	M = 2.864	1.227	0.221	ns	0.169	ns
Social Capital (SC)	M = 3.281	M = 3.120	1.589	0.113	ns	0.208	ns
Natural Capital (NC)	M = 2.848	M = 2.700	1.419	0.157	ns	0.183	ns
Physical Capital (PC)	M = 3.269	M = 3.094	1.829	0.068	†	0.256	ns
Cultural Capital (CC)	M = 3.164	M = 3.038	1.172	0.242	ns	0.149	ns
Political Capital (PLC)	M = 2.905	M = 2.861	0.39	0.697	ns	0.049	ns
Barriers (BAR)	M = 3.740	M = 3.648	1.25	0.212	ns	0.167	ns

TABLE 2: Comparison of cooperative members and non-members across technology-related outcomes, livelihood capitals, and barriers

Note: Members, n = 283. Non-members, n = 72. *** p < 0.001; * p < 0.05; † p < 0.10; ns = not significant. Cohen's d: 0.20 = small, 0.50 = moderate, 0.80 = large. TU = Technology Use Level; TS = Technology Suitability; EI = Economic Impact; AI = Adoption Intention. Source: Primary survey data (2025)

The difference in Technology Suitability is consistent with the cooperative service environment described in the previous sections. Training, demonstrations, technical guidance, and interaction with other farmers expose members to technologies under familiar production conditions. Such exposure allows farmers to assess practical relevance, operating requirements, compatibility with existing practices, and expected benefits before regular use. This process reflects the knowledge, persuasion, trial, and implementation stages of innovation adoption [27]. Research on agricultural learning also shows that farmers draw on both formal technical advice and peer experience when evaluating unfamiliar technologies [22,31-33]. Kenyan dairy studies have similarly documented the importance of extension contact, farmer training, group participation, and local production conditions in shaping engagement with dairy innovations [19,24,25]. The present finding therefore adds an institutional dimension by showing a membership difference in perceived suitability alongside the larger difference in current technology use.

Economic Impact was slightly higher among members, M = 3.040, SD = 0.837, than among non-members, M = 2.792, SD = 1.015. However, the difference was not statistically significant, t = 1.953, p = 0.052, d = 0.266. The result therefore provides insufficient evidence of a membership-related difference in the overall Economic Impact construct. This finding is important because greater technology use does not necessarily translate immediately into measurable economic gains. Economic returns depend on the type of technology used, scale of application, input costs, production conditions, market prices, and the length of time over which benefits are realised. The non-significant difference therefore warrants a distinction between technology engagement and economic outcomes.

Adoption Intention also did not differ significantly between members, M = 3.826, SD = 0.796, and non-members, M = 3.688, SD = 0.668, t = 1.335, p = 0.183, d = 0.187. Both groups therefore expressed broadly similar intentions to continue or expand technology use, despite the substantial difference in current Technology Use Level. This pattern suggests a gap between intention and realised use. Non-members reported comparable future intentions but lower current utilisation, indicating that willingness to adopt does not necessarily translate into implementation when farmers face constraints in access to training, technical assistance, demonstrations, inputs, or coordinated services.

None of the seven livelihood capital constructs differed significantly between cooperative members and non-members. The comparisons produced p = 0.146 for Human Capital, p = 0.221 for Financial Capital, p = 0.113 for Social Capital, p = 0.157 for Natural Capital, p = 0.068 for Physical Capital, p = 0.242 for Cultural Capital, and p = 0.697 for Political Capital. Effect sizes were small, ranging from d = 0.049 for Political Capital to d = 0.256 for Physical Capital. Perceived barriers also showed no statistically significant difference, p = 0.212, d = 0.167.

These non-significant findings do not demonstrate equality between cooperative members and non-members. They indicate that the study found insufficient evidence of group differences within the capital and barrier measures used. Nevertheless, the substantial difference in Technology Use Level was not accompanied by comparably large differences in the broad livelihood capital indices. The pattern therefore provides some support for the institutional explanation advanced in the Introduction. Membership-related differences appeared to be concentrated more strongly in the organisation of technology support than in general differences in livelihood resources.

Previous studies have linked cooperative participation with improved access to extension, productive services, markets, and agricultural technologies [10,18,20]. From a transaction-cost perspective, organised training, technical follow-up, peer learning, and coordinated service access reduce the effort and uncertainty involved in identifying, assessing, and applying technologies [4-7]. The present findings extend this literature by showing that the largest differences between members and non-members occurred in actual technology use and perceived technology suitability, while no significant

differences were observed across the seven livelihood capital constructs. This suggests that cooperative participation may operate through institutional access to technology-related services rather than through substantially different livelihood capital endowments.

The cross-sectional design prevents causal attribution of higher Technology Use Level to cooperative membership. Farmers with stronger prior interest in dairy technologies might have been more likely to join cooperatives. Differences in farm size, herd characteristics, infrastructure, production orientation, service availability, or location might also influence both membership and technology engagement.

The absence of statistically significant differences between cooperative members and non-members across the seven measured livelihood-capital dimensions, alongside the higher Technology Use Level among members, is consistent with an institutional-support explanation. However, these capital dimensions were examined as comparison variables rather than statistical controls. Their non-significant differences do not establish equivalence between the groups or rule out confounding by other household, farm, institutional or location characteristics. The observed membership-related differences therefore suggest a potential role for coordinated institutional support, but they do not establish that cooperative membership or institutional support caused higher technology use.

The findings have two practical implications. First, strengthening cooperative membership alone is unlikely to address technology-use gaps unless membership provides access to effective services. Priority should therefore be given to practical training, demonstrations, technical follow-up, reliable information, and coordination with extension agencies and technology providers. Second, the similar Adoption Intention scores among members and non-members indicate that farmers outside cooperative structures also express interest in technology. Selected cooperative training and extension activities could therefore be extended to non-members through open demonstrations, farmer field days, public extension partnerships, and other inclusive outreach arrangements.

Reported economic outcomes by cooperative membership

Figure *3* compares self-reported production, cost, and income outcomes between cooperative members and non-members. Across all three indicators, a larger proportion of cooperative members reported favourable economic outcomes.

Production outcomes differed significantly by cooperative membership, $\chi^2 = 32.321$, $df = 4$, $p < 0.001$. Among cooperative members, 68.5% reported production increases of at least 10%, compared with 56.1% of non-members. The difference of 12.4 percentage points shows that production gains of at least 10% were reported more frequently by members. The chi-square statistic, however, tested differences across the full distribution of production-increase categories rather than the two combined percentages alone.

Cost reduction was reported by 74.4% of cooperative members and 57.9% of non-members. The difference was statistically significant, $\chi^2 = 5.491$, $df = 1$, $p = 0.019$. Reported income outcomes also differed significantly by membership status, $\chi^2 = 14.864$, $df = 2$, $p = 0.001$. An income increase was reported by 79.1% of members and 56.9% of non-members, producing the largest descriptive difference at 22.2 percentage points.

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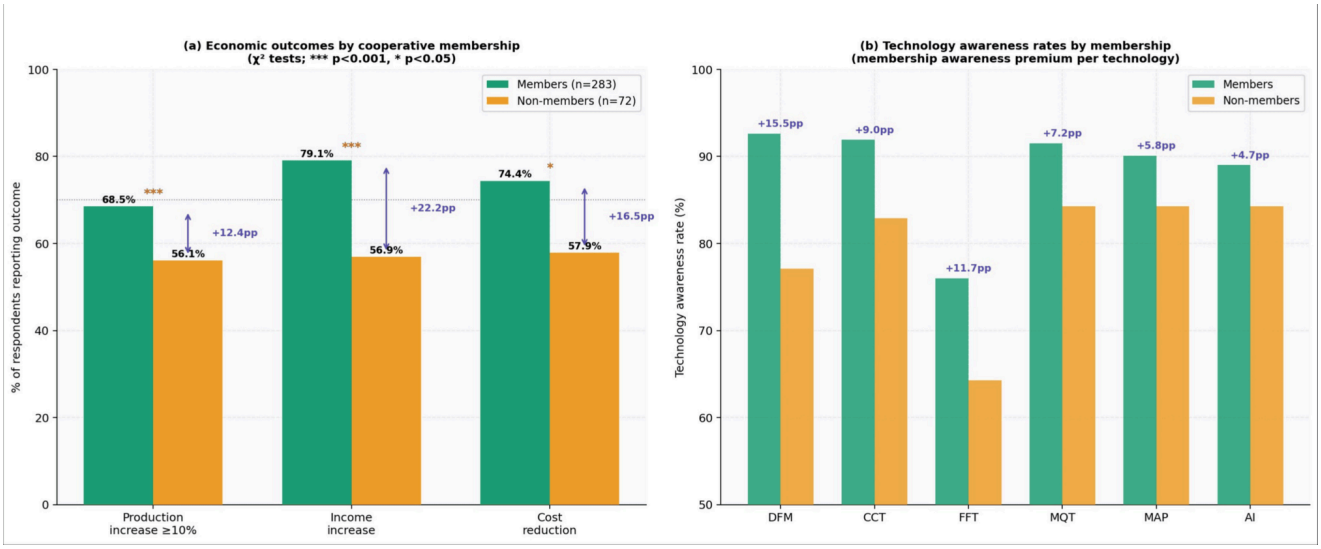


FIGURE 3: Reported economic outcomes and technology awareness by cooperative membership

These findings show an association between cooperative membership and favourable self-reported economic outcomes. The institutional services identified in the first two sections provide plausible mechanisms for this pattern. Training and technical follow-up support more effective technology application, while coordinated access to inputs reduces search and procurement difficulties. Market information, quality requirements, collective marketing, and links with buyers may also influence production costs and the conditions under which farmers sell milk.

This interpretation is consistent with transaction cost theory, which explains how collective institutions reduce the costs of obtaining information, accessing services, negotiating with buyers, and coordinating market participation [4-7]. The findings also correspond with empirical evidence linking cooperative participation with technical efficiency, market access, and welfare outcomes [10,14,19]. Chagwiza et al. [14], for example, reported stronger dairy performance among cooperative members in Ethiopia, while Ngeno [19] found welfare differences associated with participation in dairy hubs in Kenya. These studies provide relevant points of comparison, although differences in institutional arrangements, study populations, outcome measures, and research designs limit direct comparison with the present findings. The present study adds evidence from Uasin Gishu County by showing that membership was associated with differences across several specific self-reported economic outcomes, while the broader Economic Impact construct did not differ significantly between groups.

The findings do not establish cooperative membership as the cause of the reported economic differences. Members and non-members might have differed in previous experience, herd composition, farm size, production orientation, record-keeping, market participation, or location. Farmers with stronger economic performance might also have been more likely to join or remain in cooperatives. In addition, the outcomes relied on respondents' retrospective reports rather than longitudinal farm accounts, milk-delivery records, or financial statements. The results therefore represent membership-related associations within the study sample.

The categorical outcomes should also be interpreted alongside the Economic Impact construct reported in the last section. Although cooperative members recorded a higher mean Economic Impact score, the difference was not statistically significant, $p = 0.052$. In contrast, the separate categorical indicators of production increase, cost reduction, and income change showed statistically significant membership differences. This variation reflects differences in measurement. The composite construct captured a broader assessment of perceived economic effects, while the categorical questions measured specific reported outcomes. The significant categorical results do not alter the non-significant comparison for the overall Economic Impact construct.

The findings support continued attention to the services linking technology engagement with economic performance. Practical training, technical follow-up, suitable inputs, transparent market information, milk-quality incentives, dependable payments, and accurate record-keeping remain important priorities. Cooperatives should strengthen records on milk volumes, service use, input costs, payments, and member participation. Such records would provide stronger evidence on whether reported production, cost, and income differences persist over time.

Technology awareness by cooperative membership

Table *3* presents descriptive differences in awareness of seven dairy technologies between cooperative members and non-members. Cooperative members recorded higher awareness percentages across all technologies, with differences ranging from 4.8 to 15.4 percentage points. Since no inferential tests were conducted, these figures describe observed group patterns and do not establish statistically significant membership effects.

Digital Farm Management recorded the largest awareness difference. Awareness was reported by 92.6% of cooperative members and 77.1% of non-members, producing a gap of 15.4 percentage points. Feed Formulation Technology followed, with awareness levels of 76.0% among members and 64.3% among non-members, a difference of 11.7 percentage points.

Awareness of Cold Chain Technology was reported by 91.9% of members and 82.9% of non-members, representing a difference of 9.0 percentage points. Breed Development Methods recorded a gap of 7.6 percentage points, while Milk Quality Testing differed by 7.2 percentage points. Market Access Platforms showed a smaller difference of 5.8 percentage points. Artificial Insemination recorded the narrowest gap, with awareness reported by 89.0% of members and 84.3% of non-members.

Technology	Members (% aware)	Non-members (% aware)	Gap (pp)	Descriptive observation
Digital Farm Management (DFM)	92.60%	77.10%	15.4	Largest observed awareness difference
Cold Chain Technology (CCT)	91.90%	82.90%	9	Higher reported awareness among members
Feed Formulation Technology (FFT)	76.00%	64.30%	11.7	Second-largest observed awareness difference
Milk Quality Testing (MQT)	91.50%	84.30%	7.2	Higher reported awareness among members
Biogas and Dung Management (BDM)	87.60%	80.00%	7.6	Higher reported awareness among members
Market Access Platform (MAP)	90.10%	84.30%	5.8	Small descriptive difference

Artificial Insemination (AI)	89.00%	84.30%	4.8	Smallest observed awareness difference

TABLE 3: Technology awareness among cooperative members and non-members

Note: Awareness was measured as the percentage of respondents with a recorded awareness response for each technology. Percentage-point differences were calculated by subtracting the non-member awareness percentage from the member awareness percentage. No significance tests were reported for these technology-specific comparisons. The differences should therefore be interpreted descriptively. Source: Primary survey data, Uasin Gishu County, 2025

The consistently higher awareness levels among members are compatible with the intermediary role identified in the first two sections. Cooperative meetings, training sessions, demonstrations, extension contacts, market services, and interaction among members provide repeated opportunities to encounter and discuss dairy technologies. Previous research has linked cooperative participation with improved access to agricultural information, extension, productive services, and technologies [10,13,18]. Social-learning research further shows that farmers obtain information from peers and evaluate unfamiliar technologies through observation and interaction within trusted networks [31-33]. In the present study, the higher awareness levels among members therefore appear consistent with the combined influence of formal service provision and peer-based information exchange.

From a diffusion perspective, awareness represents the knowledge stage of technology engagement rather than completed adoption [27]. Cooperatives appear to strengthen this early stage by bringing information closer to farmers and linking it with demonstrations, technical explanations, and peer experience. However, the results in the third section show that membership differences extended beyond awareness to Technology Use Level and perceived Technology Suitability. This suggests that the cooperative contribution was not limited to information exposure but also involved support for evaluating and applying technologies.

The size of the descriptive differences varied across technologies. The wider gaps for Digital Farm Management and Feed Formulation Technology might reflect the greater need for organised explanation, practical guidance, or repeated technical support. Digital tools often require familiarity with devices, record systems, connectivity, or data interpretation, while feed formulation depends on knowledge of animal requirements, ingredient quality, ration balance, and cost. In contrast, the narrower awareness gap for Artificial Insemination might reflect its longer history of promotion through public extension, private breeding services, and dairy-development programmes.

Kenyan dairy research has documented variation in the adoption of different dairy innovations and has shown that technology choices may be interrelated [24,25]. It has also shown that dairy technology decisions are interrelated, meaning that awareness of one innovation may be influenced by exposure to complementary practices or services [25]. The present study, however, did not establish where each respondent first learned about a technology, how frequently information was received, or whether the technology was available locally. The explanations for the observed gaps therefore remain tentative.

Awareness should not be treated as evidence of access, trial, regular use, or effective application. Farmers might know about a technology but remain unable to adopt it because of cost, limited availability, infrastructure requirements, technical complexity, risk, or insufficient follow-up support. This distinction reinforces the argument developed in the Introduction that dairy technology engagement depends on coordinated technical, financial, institutional, and market support rather than information provision alone.

The findings highlight the value of cooperative communication channels while also showing the importance of reaching farmers outside cooperative structures. County extension services, research institutions, farmer training schools, agro-dealers, private service providers, and cooperatives should coordinate information delivery so that technical knowledge

is not restricted by membership status. Awareness activities should also be accompanied by demonstrations, practical training, and technical follow-up, particularly for technologies requiring specialised knowledge, equipment, finance, or continued support.

Manager-reported three-tier adoption model

A cooperative manager, KII-01, described a three-tier approach (Figure *4*) used to group members according to their level of technology engagement. The manager estimated approximately 60% of members were in the basic tier, 30% in the intermediate tier, and 10% in the advanced tier. These proportions were informant estimates rather than categories measured through the quantitative survey. They therefore represent one manager's account of cooperative programming rather than population estimates.

The basic tier comprised members who had joined the cooperative but used few dairy technologies. According to the manager, support for this group focused on introductory training, demonstrations, exposure to other farmers' experiences, and access to basic inputs. These activities aimed to reduce uncertainty and build confidence during the early stages of technology engagement. The manager described this group as the most difficult to support because members often required encouragement and practical evidence before progressing from awareness to trial.

The intermediate tier included members who had begun using practices such as silage preparation, farm record-keeping, and improved feeding systems. Support included field-school training, farm visits, interaction with more experienced farmers, market information, and technical assistance for specific adoption challenges. The manager regarded these members as responsive to practical training and as having considerable potential to expand their use of dairy technologies.

The advanced tier comprised an estimated 10% of members who combined several technologies and management practices related to feeding, reproduction, record-keeping, waste management, energy, water conservation, and milk production. KII-01 described these members as practising 'organised farming':

'The top ones are doing organised farming, which we have adopted technology. They do soil testing, mini milkers, they are talking about water conservation, they are talking about the use of solar, biogas, because they have done zero grazing, they can be able to collect dung.'
(KII-01, Cooperative Manager)

The reported approach is broadly consistent with the innovation-decision process described in Diffusion of Innovations theory, where farmers move through knowledge, persuasion, decision, implementation, and confirmation [27]. It should not, however, be treated as a direct application of Rogers' adopter categories. The cooperative used three locally defined levels based on technology engagement and support needs, while the theory identifies five adopter categories based mainly on the timing of adoption.

Within the manager's account, the basic tier required introductory information, demonstrations, and reduced uncertainty. The intermediate tier required practical skill development, problem-solving support, and technical follow-up. The advanced tier received more specialised management guidance and also provided local examples for demonstrations and peer learning. The model therefore illustrates how one cooperative attempted to align training content with members' existing knowledge and experience rather than offering the same programme to all farmers.

This differentiated approach is relevant because dairy technologies vary in cost, complexity, supporting-service requirements, and compatibility with existing farm practices. Farmers beginning with basic feeding or record-keeping practices have different training needs from those combining improved breeding, mechanised milking, renewable energy, water conservation, and waste-management systems. Agricultural learning research shows that practical training, repeated technical interaction, and observation of peers influence how farmers assess and apply technologies [23,31-33]. Kenyan dairy studies also report substantial variation in farmers' engagement with feeding, breeding, management, digital, and organisational innovations [24,25].

The advanced tier might also strengthen social learning by providing locally observable examples of technology use. Farmers often place greater weight on evidence from familiar production environments than on general technical recommendations [31,32]. Demonstration farms and experienced members may therefore help reduce uncertainty regarding technology requirements, performance, and suitability. However, the study did not examine whether farmers in the basic and intermediate tiers observed advanced members or whether such observation influenced their subsequent decisions.

The findings do not demonstrate the effectiveness of the three-tier approach. The study did not independently classify members into the reported groups, establish formal criteria for tier assignment, compare outcomes across tiers, or monitor movement between tiers over time. The evidence documents an institutional approach reported by one cooperative manager rather than a validated adoption model.

For cooperative practice, the approach provides a possible basis for organising extension and training services. Cooperatives should assess members' current knowledge, experience, available resources, and technology use before selecting training content. Clear criteria should guide placement within each support level, while participation, technology use, and progression should be recorded consistently. Such documentation would permit future evaluation of whether differentiated support is associated with sustained technology use, movement between engagement levels, and improved production or economic outcomes.

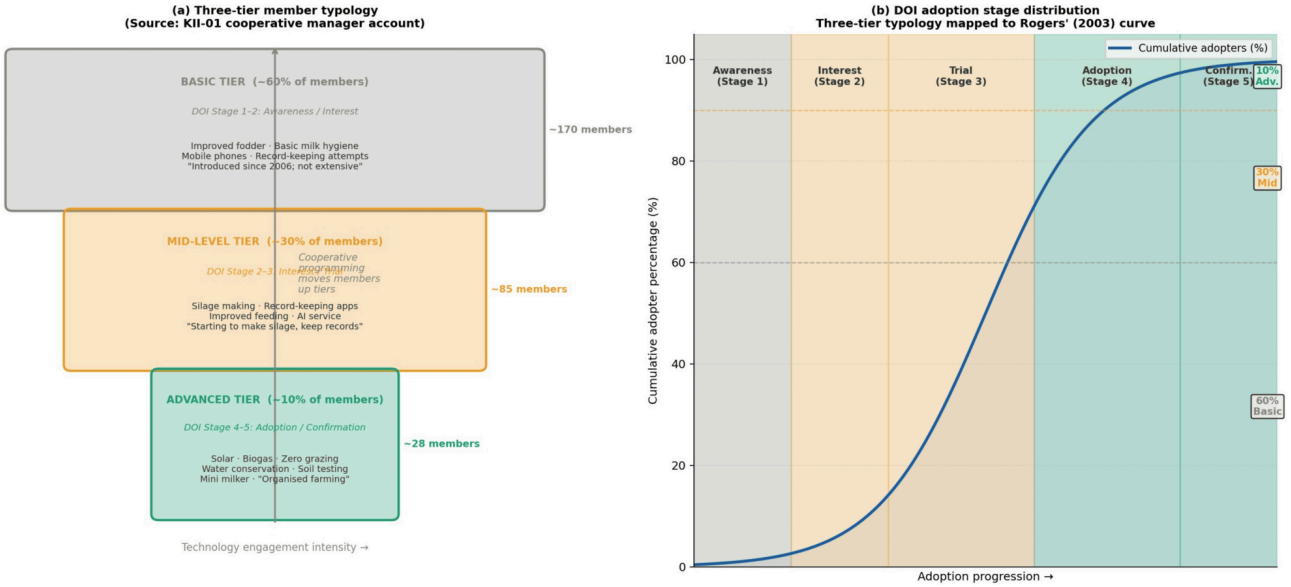


FIGURE 4: Cooperative three-tier adoption typology and DOI stage mapping

DOI = Diffusion of Innovations

Gender-inclusive joint household training

A cooperative manager, KII-01, described a mismatch between participation in cooperative training and responsibility for routine dairy activities. According to the manager, men had historically attended many cooperative meetings and training sessions, while women performed much of the daily work associated with livestock care and household dairy management:

'When you do trainings, all the time when you call for meetings, you find those who have time to go are male. The men themselves, the owners of those homes. When you go to the farms you find that people doing farming are women, they are the ones with the animals and the domestic work.'
(KII-01, Cooperative Manager)

This account points to a possible gap between access to technical knowledge and responsibility for applying it. Where the household member attending training differs from the person responsible for feeding, milking, hygiene, animal-health observation, and record-keeping, information might reach the farm indirectly or incompletely. Previous research has similarly cautioned against treating households as single decision-making units because women and men often differ in their productive roles, access to services, control over resources, and participation in agricultural decisions [36-40].

The manager reported that the cooperative responded by encouraging joint household attendance at training sessions. Under this arrangement, male and female household members received the same practical instruction instead of depending on one participant to transfer the information to another. Direct attendance also allowed women involved in routine dairy work to observe demonstrations, ask questions, and practise recommended procedures under supervision.

KII-01 further explained that the cooperative used women's involvement in household milk production as an entry point for increasing their participation in training and dairy-related discussions. This approach sought to strengthen women's technical involvement within existing household production arrangements. It should not, however, be interpreted as evidence of wider changes in decision-making authority, labour relations, or control over dairy income. The study did not collect longitudinal household-level data on these outcomes.

The manager reported that the cooperative's membership composition had reached approximately 53% men and 47% women following the introduction of joint household training. These figures refer only to the cooperative managed by KII 01 and describe the manager's account of changes within that organisation. They should not be compared directly with the quantitative survey results, which showed that cooperative members across all sampled cooperatives comprised 57.6% men and 42.4% women (n = 283). The two sets of figures represent different populations, data sources, and analytical purposes. The survey provides a cross-sectional description of the study sample, whereas the interview describes one cooperative's reported experience after implementing a specific institutional approach.

The manager also associated the gender inclusive training programme with a reported 200% increase in milk collection over two years within the same cooperative. This observation reflects the manager's account and was not independently verified using cooperative records or a comparative evaluation design. According to the account, women's direct participation in training supported more consistent implementation of recommended practices:

'When we started training all of them, we've seen progress, because women implement.'
(KII-01, Cooperative Manager)

This reported change illustrates how the manager perceived the value of joint training, but it does not establish a causal programme effect. The study did not independently verify the milk-volume records, compare outcomes with another cooperative, or account for changes in herd size, cooperative membership, prices, feed availability, weather, or other conditions during the same period. The 200% figure should therefore be interpreted as a manager-reported increase in cooperative milk collection rather than as confirmed evidence of productivity growth resulting from joint training.

The qualitative findings reinforce the argument that inclusive service delivery depends on who receives technical information, not only on who holds cooperative membership. Women involved in daily dairy management require direct access to training, demonstrations, extension advice, and follow-up support. This interpretation is consistent with evidence showing that women's participation in agrifood systems is shaped by unequal access to productive assets, services, technologies, finance, and decision-making opportunities [36-40].

Joint household training also provides an institutional mechanism for addressing the separation between formal representation and practical implementation. It brings household members involved in investment decisions together with those responsible for routine technology use. This arrangement might improve shared understanding of labour requirements, costs, operating procedures, and expected outcomes. The present study did not measure these household processes directly, so this mechanism remains a plausible interpretation rather than a tested effect.

For cooperative practice, training schedules should recognise the time and work responsibilities of both women and men. Invitations should explicitly include household members involved in daily dairy management, while practical sessions should provide equal opportunities to participate in demonstrations and technical exercises. Cooperatives should disaggregate attendance and follow-up records by sex and examine changes in knowledge, technology use, decision participation, and economic outcomes. Such monitoring would provide stronger evidence on whether joint household training improves inclusion and supports consistent technology implementation.

Reported market pressure and cooperative responses

Interview accounts from cooperative managers identified pressure from large dairy processors as a concern for cooperative stability. KII-01 described a pattern in which processors offered attractive prices directly to farmers during favourable market periods, drawing milk away from the cooperative, before reducing prices after the cooperative's bargaining position had weakened:

'They use the divide-and-rule strategy. They come better for us to the farmers and they stop buying milk from the cooperative. But finally, once the commodity is weak, then they lower the prices so they suppress. So you paralyze so that you can control.'
(KII-01, Cooperative Manager)

This quotation represents the manager's interpretation of processor behaviour rather than independently verified evidence of predatory pricing, coordinated market manipulation, or unfair competition. It nevertheless illustrates the uncertainty faced by cooperatives when members shift milk deliveries to alternative buyers offering temporary price advantages. Reduced delivery volumes might weaken collective bargaining, disrupt cash flow, increase milk-handling costs per unit, and limit the cooperative's ability to plan and maintain member services.

The account is consistent with wider literature on transaction costs, collective marketing, and changing power relations within agricultural value chains [1,4-8,35]. Producer organisations support smallholders by aggregating output, sharing market information, coordinating sales, and negotiating with buyers [1,8,17]. These functions reduce some of the costs and uncertainties associated with individual market transactions. Their effectiveness, however, depends on sufficient delivery volumes, organisational credibility, reliable payments, and continued member participation.

Rapid food-system transformation has increased the influence of processors, retailers, logistics providers, and specialised service companies within agricultural markets [35]. Such changes provide farmers with additional marketing opportunities but also expose cooperatives to greater competition for members' produce. Cooperatives therefore need to offer more than collective sales. Their continued relevance depends on service quality, transparent governance, dependable payment arrangements, market information, and the ability to respond to members' production and technology needs. The emphasis on bundled technological and institutional support in recent agrifood research also suggests that stable marketing arrangements form part of the wider environment needed to sustain agricultural innovation [34].

Cooperative managers identified regular communication, timely market information, reliable payments, service quality, collective negotiation, and financial capacity as important responses to market pressure (Figure *5*). The survey finding that 74.6% of respondents would recommend their cooperative indicates generally favourable perceptions of cooperative services. However, willingness to recommend a cooperative does not directly measure members' commitment to continue delivering milk during periods of price competition. It should therefore not be interpreted as evidence of sustained member loyalty.

Market uncertainty also has implications for technology engagement. Farmers might hesitate to invest in technologies requiring substantial capital where milk prices, payment schedules, or access to buyers remain unstable. Reliable marketing, quality incentives, technical support, and price information might reduce part of this uncertainty. Conversely, declining milk volumes and weak cash flow might restrict the cooperative's ability to provide training, extension support,

input facilitation, and credit arrangements. This relationship reflects the transaction-cost argument developed in the Introduction, since market instability increases uncertainty surrounding both technology investment and expected returns [4-7].

The present study did not test these pathways quantitatively. It did not examine milk-price trends, processor contracts, member delivery records, switching behaviour, or the financial performance of participating cooperatives. The proposed relationship between market stability, cooperative services, and technology engagement therefore remains an interpretation informed by the interview accounts and wider literature rather than a confirmed study finding.

The results point to the importance of market transparency and cooperative risk management. Cooperative leaders should provide members with regular information on prices, deductions, payment schedules, and changing market conditions. Accurate milk-delivery records, timely payments, accessible complaint procedures, and clear explanations of cooperative decisions would also strengthen trust between members and management. Buyer diversification and written supply agreements might reduce dependence on a single processor, although such arrangements require careful legal, financial, and market assessment.

County agencies may support these efforts through market-information services, contract guidance, mediation procedures, and investigation of formally reported unfair trading practices. Any financial assistance intended to address temporary cooperative cash-flow constraints should include clear eligibility, accountability, and repayment conditions. These measures would support cooperative stability while preserving farmers' freedom to select their preferred marketing channels.

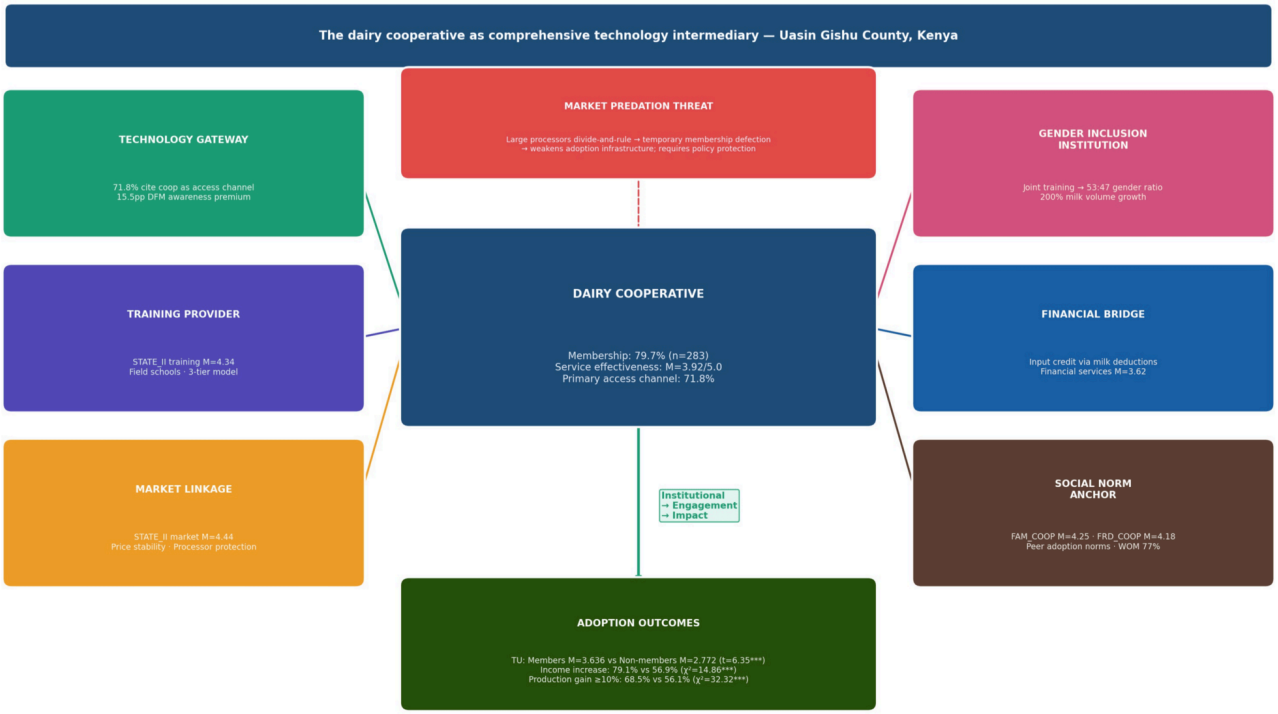


FIGURE 5: The Dairy Cooperative as comprehensive technology adoption intermediary

Conclusions

The study examined how dairy cooperatives support technology engagement among dairy value-chain actors in Uasin Gishu County. The findings indicate that cooperatives perform a broader role than milk collection and marketing by linking members with training, technical information, markets, inputs, peer networks, and other service providers.

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Igube N J, Mugalavai V K, Omega J A (November 12, 2026) Beyond Milk Marketing: Dairy Cooperatives as Comprehensive Technology Intermediaries in Smallholder Value Chains - Evidence from Uasin Gishu County, Kenya. Cureus J. Agri. Food Sci 2 : es44497-026-00365-5. DOI https://doi.org/10.7759/s44497-026-00365-5

Cooperative membership was associated with higher technology use and more favourable perceptions of technology suitability. However, members and non-members did not differ significantly across the seven livelihood capital constructs. This pattern suggests that technology engagement may be more closely related to institutional support, including practical training, demonstrations, information exchange, peer learning, and technical follow-up, than to differences in livelihood capital endowments. The qualitative findings further showed that cooperatives adapted their support to members' different levels of technology engagement and promoted joint household training, recognising differences in farmers' experience and the importance of reaching household members responsible for routine dairy activities. Manager-reported market pressures also highlighted the importance of stable member relations, transparent pricing, timely payments, accurate records, and effective communication.

For cooperative leaders, the findings support continued investment in extension, training, market information, and technical follow-up, alongside improvements in credit access and input facilitation. Extension agencies, research institutions, private service providers, and county departments should collaborate with cooperatives while maintaining access to services for farmers outside formal cooperative structures. Stronger coordination among these actors could support continuity from technology awareness and practical trials to regular use and outcome assessment. Nevertheless, the findings should be interpreted in light of the study's limitations. The cross-sectional design does not establish causality, while the purposive selection of Ainabkoi, Kapseret, and Moiben limits wider generalisation. Economic outcomes were based on respondents' reports rather than longitudinal farm records, and several institutional practices and programme figures derived from key informant accounts were not independently verified. Furthermore, the qualitative sample of four cooperative managers and three county livestock officers did not represent the full range of farmers, processors, financial institutions, technology suppliers, and private service providers within the dairy value chain. Future research should follow cooperative members and non-members over time, compare cooperatives at different levels of organisational development, and account for farm, household, and location characteristics associated with technology use. Combining survey data with farm accounts, cooperative records, milk-delivery data, and direct observations of technology use would provide stronger evidence of the relationship between cooperative services, technology adoption, and economic outcomes. Overall, dairy cooperatives occupy an important position within the local technology-support system, although their contribution depends on service quality, institutional coordination, financial capacity, and inclusive access. The higher technology use and more favourable perceptions of technology suitability reported by cooperative members, despite the absence of significant differences across the seven measured livelihood-capital dimensions, suggest the potential importance of coordinated institutional support. However, the use of livelihood-capital measures as comparison variables rather than statistical controls, together with the possibility of unmeasured confounding, prevents causal conclusions. The findings should therefore be interpreted as membership-related associations within the study sample.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Nkiruka J. Igube, Violet K. Mugalavai, Joseph A. Omega

Acquisition, analysis, or interpretation of data: Nkiruka J. Igube, Violet K. Mugalavai, Joseph A. Omega

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Disclosures

Plant subjects: All authors have confirmed that this study did not involve any herbarium specimen.

Human subjects: Consent was obtained from all participants in this study. National Commission for Science, Technology and Innovation, Kenya issued approval NACOSTI/P/25/4177107. This is to certify that Ms. Nkiruka Jacinta Igube of the University of Eldoret has been licensed to conduct research in accordance with the provisions of the Science, Technology and Innovation Act, 2013 (Rev. 2014), in Uasin Gishu County, on the topic 'Adoption of Technological Innovations Along the Dairy Value Chain in Uasin Gishu County: Challenges and Opportunities', for the period ending 23 July 2026.

Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following:

- **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work.
- **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work.
- **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Data Availability Statements

The datasets (and/or code) supporting this study are available from the corresponding author upon reasonable request.

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