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Plants and procedures used for traditional processing of sour milk (*Amakamo*) by the Bahima of Kiruhura District, Uganda

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Abstract

Amakamo, a traditionally fermented milk product has been consumed by the cattle keeping communities of South-Western Uganda for a long time but its production process is not well understood. To achieve this, a cross-sectional study was carried out in Kiruhura District to document the plants and procedures followed during *amakamo* processing though interviews and focus group discussions. The plants were collected, identified and vouchers deposited at the Makerere University Herbarium. A total of 108 respondents were interviewed, majority of whom were females (92.6%), had experience in *amakamo* processing ranging between 20 and 29 years (69.4%), and learnt the skill from their parents (92%). Most (55.6%) respondents were aged between 31 and 40 years, processed *amakamo* daily (88%), mainly for home consumption (92.6%). The key steps in *amakamo* processing include cream separation, boiling, cooling, backslopping, fermentation and curd breaking. The most reported cause of *amakamo* processing failure is the plant used to smoke the vessels (60. 2%, n=108), followed by poor quality starter culture (18.5 %, n=108). The commonest sign of unsuccessfully processed *amakamo* is milk separation (60.2 %, n=108). Eighteen plants belonging to 14 families were reported most of which (16.7%) belong to Poaceae family. All respondents (100%) cited *Thunbergia alata, Hoslundia opposita*, *Albizia coriaria*, *Combretum molle*, *Loudetia kagerensis* and *Hyparrhenia filipendula* as useful plants in *amakamo* processing. The most predominant plant life forms were shrubs (33.3%) followed by trees (27.8%). Most plants (27.8%) were used to scrub and smoke fermentation vessels. Aerial parts were the most commonly (50%) used parts and almost all (94.4%) of the plants used were from wild habitats. Further studies should be done to investigate the phytochemical composition of the plants used to smoke fermentation vessels and how they affect the quality of the *amakamo.*

Key words: *Amakamo; Fermented milk; Kiruhura District; Plants; Uganda*

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Introduction

Fermentation is a food processing technology that relies on the activity of microorganisms to break down food constituents under anaerobic conditions. It is one of the valuable and efficient preservation methods that has been used for long (Akabanda, 2025). Fermentation of milk occurs with the help of lactic acid bacteria that are either intentionally added to milk or occur naturally in there (Agyei *et al.*, 2020). Fermentation helps to preserve and extend the shelf life of milk especially in remote areas where refrigeration services are not readily available (Akabanda, 2025). It also contributes to enhancement of nutritional value and bioavailability of food nutrients (Enahoro *et al.*, 2018). Additionally, fermented foods have unique flavours that result from the action of fermentative organisms (Lee and Lucey, 2010). For this reason, many indigenous communities employ milk fermentation technology to produce a variety of products (Agyei *et al.*, 2020; Owusu-Kwarteng *et al.*, 2020). The practice of milk processing using indigenous technologies dominates most of the native pastoral communities of Africa (Hawaz *et al.*, 2025).

The cattle keeping communities of South-western Uganda, particularly the Bahima, utilize traditional fermentation technologies to process a sour milk product known as *amakamo* which is worth documenting. Documentation of information about traditional milk processing practices is very important because it yields innovations that can easily be adopted, standardized and further commercialized by the local communities (Hawaz *et al.*, 2025). Several countries have been able to document information about their traditional milk products which has contributed to their standardization and commercialization for example *amasi* in South Africa (Maleke *et al.*, 2021), *mabisi* in Zambia (Moonga *et al.*, 2019) and *mursik* in Kenya (Nduko *et al.*, 2017). In Uganda, documentation of production methods has been attempted for some traditional milk products such as *Kwerionik* (Nakavuma *et al.*, 2012) and *bongo* (Gulaita, 2015; Mukisa *et al.*, 2020). However, despite the existence of *amakamo* since pre-colonial times, hardly any literature exists on its production methods.

It is further reported that during the production of *amakamo*, several plants are used (Schutte, 2013). The practice of using plants during processing of milk products is wide spread in Africa. For example, in Ethiopia researchers reported the use of plants like *Olea africana, Juniperous procera, Eucalyptus globulus* among others to smoke fermentation vessels used in processing *ergo* (Mekonnen and Lemma, 2011; Gebeyew *et al.*, 2016). In addition, several researchers have reported the use of *Combretum molle* to smoke fermentation vessels for example during the production of *kivuguto* in Rwanda (Karenzi *et al.*, 2013), *kwerionik* in Uganda (Nakavuma *et al.*, 2012), *kule naoto* and camel milk in Kenya (Mathara *et al.*, 2004; Wayua *et al.*, 2012). Furthermore, in Namibia, during the production of *omashikwa*, roots of either *Boscia albitrunca* or *Andasonia digitata* are added to milk before it is fermented (Misihairabgwi and Cheikhyoussef, 2017). However, the plants used in *amakamo* processing are hardly documented. Documenting these plants is important because it creates awareness about their conservation status. Secondly, it helps to prevent cultural erosion among the communities using these plants (Dlamini, 2024).

The objectives of this study therefore were to document the steps followed during *amakamo* processing and the plants that are used during its production. Documenting this information will not only contribute to preservation of the culture of *amakamo* processing and sustainable use of the plants but will also avert loss of information.

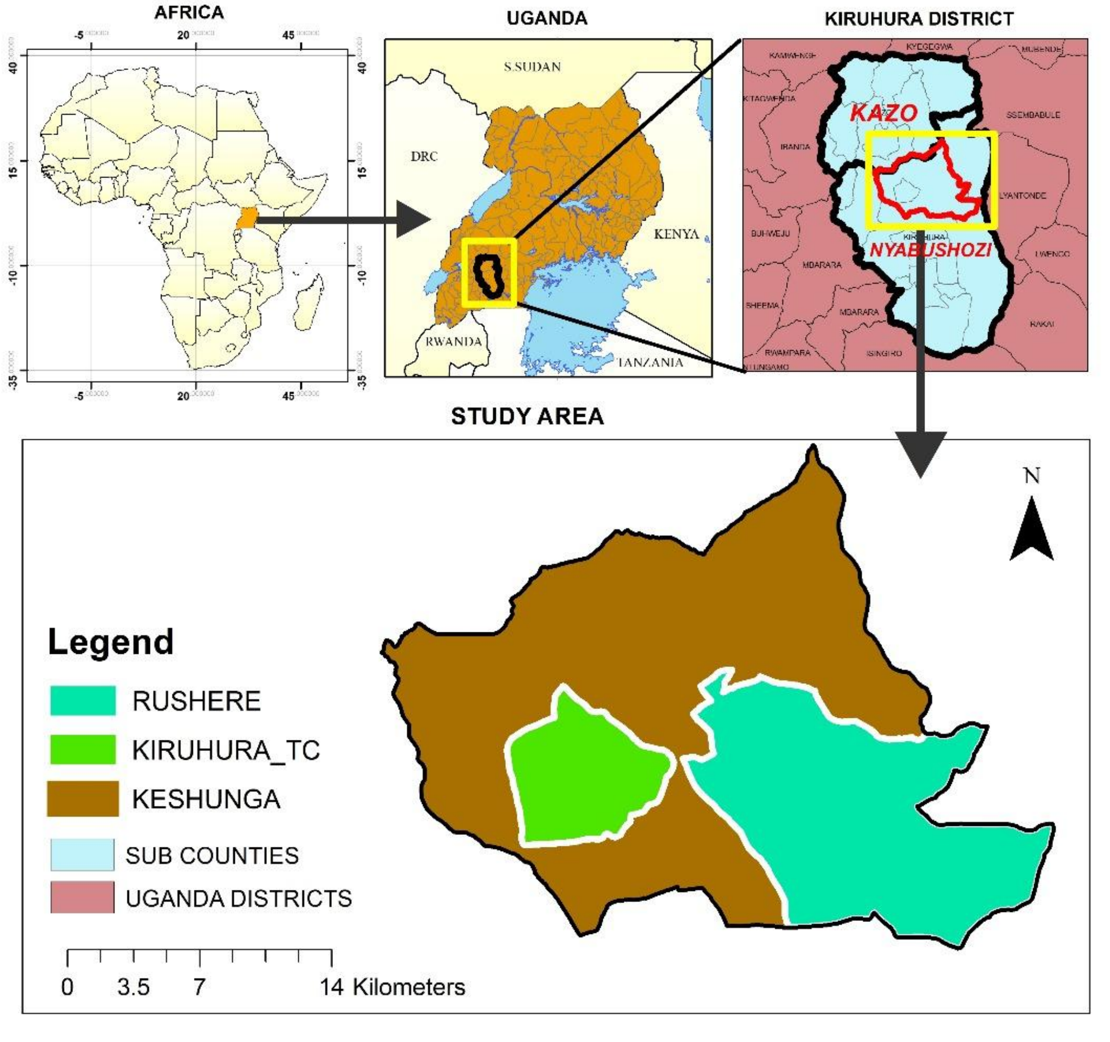
Materials and methods

Study area

This study was carried out in Kiruhura District located 62 km North-East of Mbarara City and about 245 km South-West of Kampala, the capital City of Uganda. The district lies on 0.3320°S and 30.8039°E of the equator. It is near Lake Mburo National Park. The main economic activity of the people in Kiruhura District is livestock keeping because it is located in the cattle corridor of Uganda with semi desert climate conditions. The district is also among those with high cattle population density and where the Bahima reside. These are some of the areas in Uganda that still practice traditional milk processing and where the culture is strongly upheld (UBOS, 2017; Wanyama, 2020). Kiruhura District is made up of two counties namely Nyabushozi and Kazo Counties. The current study was carried out in Nyabushozi. Nyabushozi County has eleven administrative units which include eight Sub-counties and three Town councils. The Sub-counties are Kanyaryeru, Kenshunga, Kikaatsi, Kinoni, Nyakashashara, Sanga, Kashongi and Kitura while Town councils include Kiruhura, Sanga and Rushere (https://www.kiruhura.go.ug/project/kiruhura-administrative-units, 2022). This study was carried out in three of these administrative units namely; Kenshunga, Kiruhura and Rushere. A total of six Parishes/Wards were considered in this study, two from each administrative unit namely: Nyakasharara and Rugongi parishes from Kenshunga Sub-county; Rushere and Nshwerenkye Wards from Rusherere Town Council; and Kiruhura and Nyakasharara Wards from Kiruhura Town Council (Figure 1).

Figure 1

A map of Kiruhura District showing the study area



Study design

This was a cross-sectional study carried out between 25th October and 30th November, 2024. It employed both qualitative and quantitative approaches to collect data from the respondents (Creswell and Creswell, 2017). Qualitative data were collected through key informant interviews (KIIs), non-participatory observation (NPO) and focus group discussions (FGDs). Quantitative data on the other hand were collected through semi-structured interviews (SSIs) using questionnaires.

The respondents for KIIs were purposively selected basing on the role they played in overseeing the activities along the milk value chain. Five (5) respondents participated in the KIIs including a senior community development officer (SCDO), a town clerk, an extension officer, a veterinary officer and the principal veterinary officer, Kiruhura District. The KIIs were carried out using key informant guides and the purpose was to help the researcher get an overview of the *amakamo* processing technology as well as identifying the people involved in this activity.

The respondents for the SSIs were selected randomly from the population of known traditional milk processers in the study area. These were determined using the formula for unknown population by Kothari (2004):

$$n= Z2SD2/E^2 \quad (1)$$

Where n= required sample size, Z= standard error of the mean equivalent to 1.96 at 95% confidence interval (CI), SD= standard deviation from the mean estimated at 25% (0.25), E= allowable error equivalent to 0.05. The sample size was calculated as $(1.96^2) \times (0.25^2)/0.05^2 = {\sim}96$. Considering a 10% non-response rate, the estimated sample size was 106, however to have an equal distribution of respondents, a total of 108 processors were interviewed with each Sub-county/Town Council contributing 36 respondents.

Selection of the respondents for SSIs was done through systematic random sampling (Walusansa *et al.*, 2022). Considering the required sample size of 108 respondents, 18 milk processors were recruited per Parish/Ward. The total number of all the processors from each Parish/Ward was obtained from the SCDO. The total population of the milk processors was divided by the required number of respondents to get the sampling interval. Since the number of processors was not the same for all Parishes and Wards, the sampling interval varied. It was 4 for Nyakasharara Parish, 6 for Rugongi Parish, 10 for Rushere Town Council, 10 for Nshwerenkye Ward, 5 for Nyakasharara Ward and 5 for Kiruhura Town Council. The SSIs were carried out using open ended questionnaires. These aimed at collecting data about *amakamo* processing and plants used from the processors. The information collected during interviews included demographics, general practices about *amakamo*, vessels used during *amakamo* processing and how they are prepared, *amakamo* processing steps, plants used during *amakamo* processing, their roles in the *amakamo* processing activity and the habitat from which they are obtained. During the interviews, the researchers also employed non-participatory observations (NPOs) to see what the respondents were demonstrating and pictures were taken with permission from the respondents. In addition, NPOs were employed during transect walks in the fields to identify the plants.

In order to rank the plants, FGDs were carried out using FGD guides. Six mixed FGDs were carried out, one per Parish/Ward. The respondents for the FGDs were selected from those that participated in SSIs. Each FGD consisted of a minimum of eight and a maximum of twelve participants including both men and women above 18 years.

Plant collection and identification

With the help of processors, the plants were located, identified by their local names, collected and sorted to remove weeds. Sample specimens were prepared following the protocol by Walusansa *et al.* (2022) and transported to the Makerere University herbarium. The plants were identified by a senior taxonomist and voucher specimens deposited.

Ethical considerations

The study was approved by the Makerere University School of Social Sciences Research Ethics Committee (MAKSSREC 08.2024.773). Written informed consent was obtained from all the respondents prior to the interviews. All interviews were conducted in the local language (Runyankole). For that reason, all the data collection tools were translated into Runyankole by a professional translator from Makerere School of Social Sciences.

Data analysis

Data from SSIs were entered into Microsoft Excel, cleaned and then exported into SPSS version IBM Statistics 26 for descriptive analysis and results presented in form of frequencies and percentages. During FGDs, the plants were analysed through pairwise ranking alongside the participants.

Results

Demographic characteristics of the respondents

The demographic characteristics of the respondents are presented in **Table 1**. Majority of the respondents were females (92.6%) aged between 31 to 40 years (55.6%) and majority were married (88%).

Table 1

Demographic characteristics of the respondents in Kiruhura District, Uganda

Variable	Description	Frequency (n=108) and percentage
Gender	Female	**100 (92.6)**
	Male	8 (7.4)
Age	18-30	20 (18.5)
	31-40	**60 (55.6)**
	41-50	10 (9.3)
	51-60	8 (7.4)
	60 and above	10 (9.2)
Marital status	Married	**95 (88)**
	Single	5 (4.6)
	Divorced	7 (6.5)
	Widow/Widower	1(0.9)

General information about amakamo processing

Table 2 shows some general information about *amakamo* processing in Kiruhura District. Most (69.4%) respondents had spent between 20 to 29 years processing *amakamo*. Majority (92%) of the respondents obtained knowledge about *amakamo* processing from their parents. A*makamo* was processed daily by most (88%) respondents and majority (92.6%) of them did so for home consumption. Moreover, most processors (96.3%) preferred to process *amakamo* from local cow milk, preferably from their own farms (93.5%).

Table 2

General information about amakamo processing in Kiruhura District, Uganda

Question	Response (n=108)	Frequency and percentage
For how long have you been processing *amakamo?*	< 10	13(12)
	10-19	5 (4.6)
	20-29	**75 (69.4)**
	>30	15 (14)
Who taught you how to make *amakamo*?	Formal trainer	9 (8)
	Parents	**99 (92)**
How often do you process *amakamo*?	Daily	95 (88)
	Weekly	13 (12)
Why do you process *amakamo*?	For home consumption	**100 (92.6)**
	For selling	8 (7.4)
From which breed of cattle do you prefer to get milk for making *amakamo*?	Local breed	**104 (96.3)**
	Any breed	4 (3.7)
	Exotic	0 (0)
Where do you get the milk you use to process *amakamo*?	Own farm	**101 (93.5)**
	Neighbour's	6 (5.6)
	Milk collection center	1 (0.9)

Vessels used during amakamo processing

Figure 2 shows that two types of vessels are used during *amakamo* processing in Kiruhura District namely; traditional and modern vessels. Modern vessels are made out of metallic and plastic materials. Traditional vessels on the other hand are made out of the gourd plant, wood, clay or sisal. The metallic vessels include saucepans (A), stainless milking cans and metallic buckets (B). The saucepan is used to boil milk destined for making *amakamo*. The metallic buckets are used as milking vessels. The plastic vessels used during *amakamo* processing include strainer/sieve (C), bucket (D) and jerry-can (E). The strainer is used to remove cream from the milk which is later used to make traditional butter (*amashita*). The jerry-cans and buckets are used as fermentation vessels by commercial *amakamo* processors.

The traditional vessels used by *amakamo* processors in Kiruhura district include: *ekirere (*F*)*, *ekishaabo (*G*)*, *enkoro (H)*, *entsimbo*, (I) *ekyanzi* (J) and *ecicunga (L)* as shown in Figure 2. *Ekirere* is the main fermentation vessel used by traditional processors. It is medium sized, about three to five liters volume, long-necked and is obtained from the gourd plant. *Enkoro* is a small gourd about a liter that is used to serve *amakamo* to children. *Ekishaabo* is the biggest of all the gourds and is long-necked measuring between 10 and 15 liters. Its function is to churn cream into traditional butter (*amashita*). *Entsimbo* which is wide mouthed, with no neck is used to store *amashita* for aging. The *ekyanzi* is made out of wood and is used to serve *amakamo* to adults. The *ekyanzi* is smoked using a special vessel traditionally called *ecicunga*. The latter is made out of clay, has a long neck with circular openings at the sides where the smoldering grasses are placed. After use, all traditional vessels are dried using a special material called *akakubiiso* (L). This is a special fishing net used to remove debris from the gourds after smoking.

Figure 2

Vessels used during amakamo processing in Kiruhura district

Amakamo pre-processing activities

Before processing *amakamo*, the vessels used for its fermentation and serving are cleaned and fumigated using specific plants that will be described later under sections on plants. Cleaning involves putting the leaves of scrubbing plants plus hot water into the vessels and shaking vigorously, pouring out the contents and rinsing with cold water. The vessels are then hung up-side down, away from direct sunlight in a special milk processing area called *orugyeegye*. Once dry, the vessels are smoked (a practice traditionally known as *okuhitira*) by directing smoke from burning woods into the vessels for at least ten minutes. The wood is removed and the process repeated at least three times for efficient smoking. For the last time, the vessels are covered while still having the smoke and put on the *orugyeegye* until the next day awaiting use. Before milk is poured into the vessels, remnants of the wood chips are removed using a special net called *akakubiiso*. No additional cleaning is done after that.

Procedures for processing amakamo

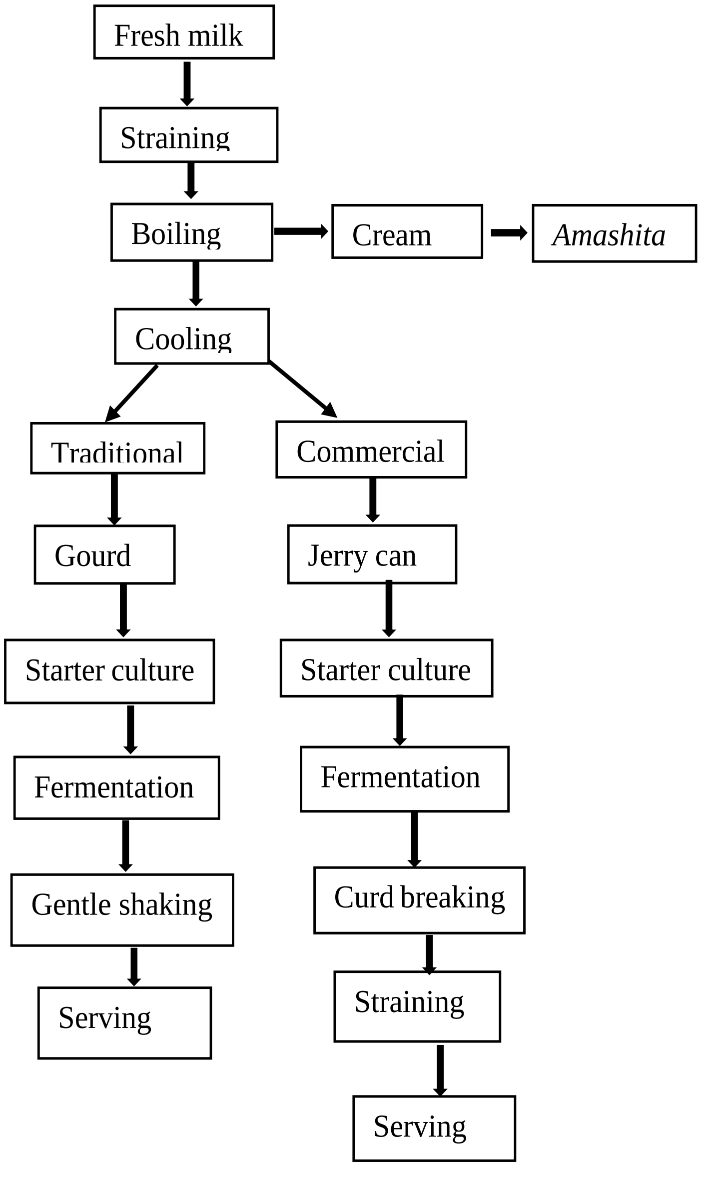
Processing of *amakamo* is done in well designated places traditionally referred to as *orugyeegye*. However, those processing for commercial purposes can use any clean and secure places at their business areas. The process of making *amakamo* starts with preparation of starter culture traditionally known as *enkamyo*. To make *enkamyo*, about 100 ml of milk is boiled immediately after milking and poured into a small clean container with a lid. It is then cooled to lukewarm temperature and inoculated with two to three drops of previous *amakamo* through backslopping. The tin is covered and kept in the designated processing area where it is wrapped with cotton sheets and the milk allowed to ferment for about eight hours. At the end of the eight hours, the preparation is ready for use as starter culture.

The steps taken to process *amakamo* in Kiruhura District are summarized in Figure 3. The milk is strained into a clean saucepan or bucket and left undisturbed for about eight hours after which the cream is removed and used to make butter *(amashita)*.The low-fat milk is then boiled and cooled to lukewarm temperature. It is then poured into a pre-smoked fermentation vessel.

Then a few drops of the starter culture (*enkamyo*) are added. The milk and *enkamyo* are mixed by gently shaking the fermentation vessels. The vessels are then covered tightly and transferred to the processing area and wrapped with layers of cotton sheets. The milk is fermented for about 17 hours, after which it is checked for presence of a curd that has a nice smell and mild sour taste. Once considered ready, traditional processors break the *amakamo* curd by gently swirling the fermentation vessels, after which the *amakamo* is transferred to the individual serving pots (*ebyanzi*). On the other hand, commercial processors use a stronger force to break the curd and sieve the *amakamo* using a muslin cloth to remove any debris before transferring the *amakamo* to fresh clean jerry-cans. The sieved *amakamo* is kept under refrigeration awaiting sale. *Amakamo* takes about two days and seven days to get spoilt in traditional vessels and under refrigeration respectively.

Figure 3

Flow chart showing the steps followed to process amakamo in Kiruhura district



Signs and causes of amakamo processing defects

Figures 4 and 5 show the signs that processors base on to know when the *amakamo* processing is not successful. The common signs of unsuccessfully processed *amakamo* are milk separation (60.2%), followed by presence of clots (13.9%) as seen in Figure 4. The major causes of product failure during *amakamo* processing include the type of plant used to smoke the fermentation vessels (60.2%), followed by poor quality starter (18.5%) as presented in Figure 5.

Figure 4

Common signs of spoilt amakamo

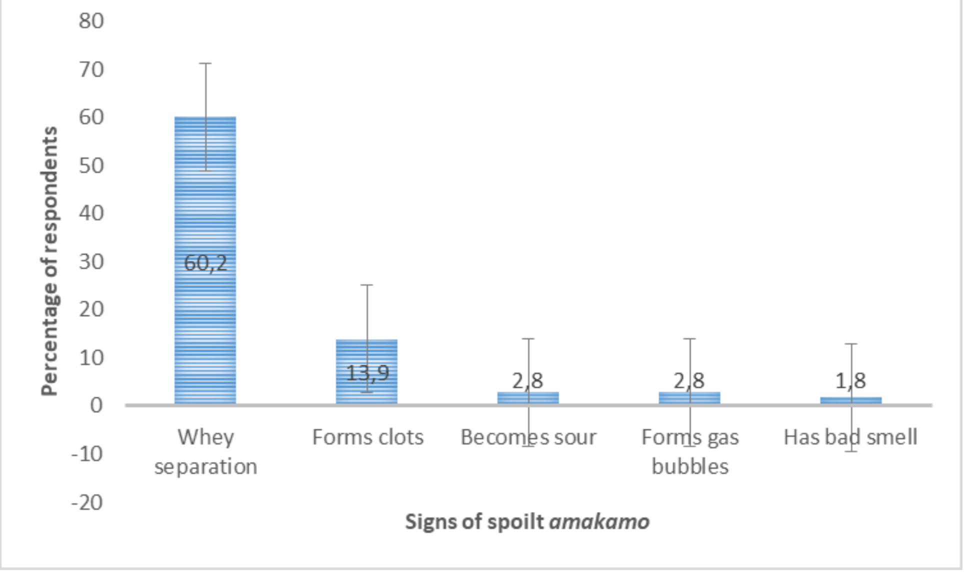
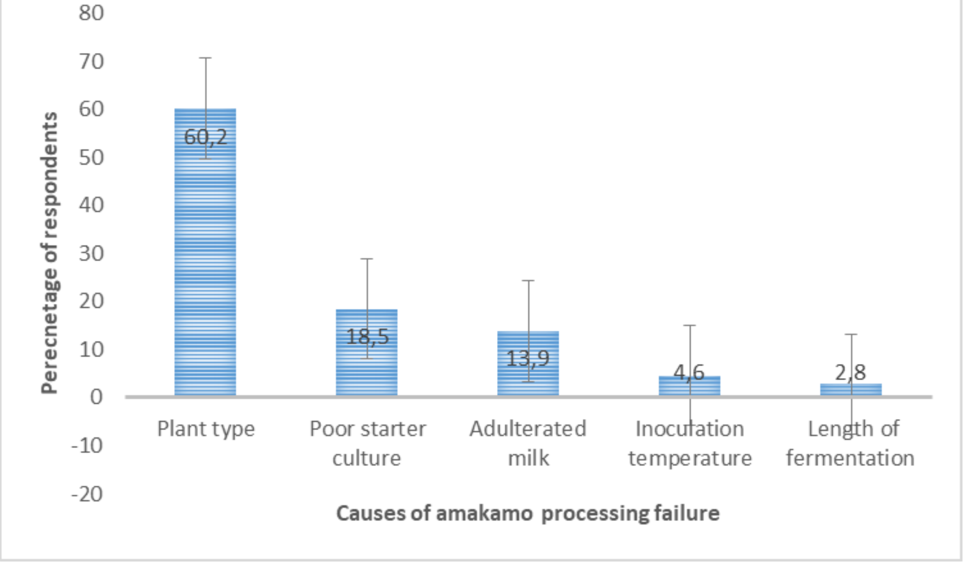


Figure 5

Common causes of amakamo processing failure



Plants used during amakamo processing

A summary of the plants used during *amakamo* processing is given in **Table 3**. A total of 18 plants belonging to 14 families were documented for use in *amakamo* processing during interviews. Three plants belong to Poaceae family whereas Acanthaceae and Asteraceae families each has two plants. The plants perform specific roles in *amakamo* processing with those used to clean and smoke vessels being more (11/18). *Hoslundia opposita, Combretum molle, Hyparrhenia filipendula, Loudetia kagerensis, Thunbergia alata* and *Albizia coriaria were* cited by all respondents. Shrubs dominated the list (6/18) followed by trees (5/18). Aerial parts were the most used parts (6/18). Almost all plants (17/18) were obtained from the wild habitat.

Table 3

Summary of the plants used during amakamo processing in Kiruhura District

Variable	Breakdown	Frequency (n=18)
Family	Acanthaceae, Asteraceae	2 each
	Anacardiaceae, Celestraceae, Combretaceae, Ebenaceae Lamiaceae, Mimosoideae, Papilionaceae, Rubiaceae, Rutaceae, Solanaceae, Tiliaceae	1 each
	Poaceae	3
Role in *amakamo* processing and most cited for that role	Cleaning vessels	*5 (H. opposita)*
	Smoking fermentation vessels	*5 (C. molle)*
	Smoking drinking pots	*1 (H. filipendula)*
	Providing insulation	*2 (L. kagerensis)*
	Making starter culture	*3 (T. alata)*
	Reconditioning fermentation vessels	*2 (A. coriaria)*
Life-forms of plants	Shrubs	6
	Herb	4
	Tree	5
	Grass	3
Part used	Aerial	9
	Stem wood	5
	Stem bark	3
	Fruit	1
Habitat type	Wild	17
	Domestic	1

Preference of plants in cleaning vessels

Five (5) plants were reported to be used to clean and scrub vessels as shown in Table 4. These include *Monechma subsessile* (*M. subsessile*), *Conyza floribunda* (*C. floribunda*), *Hoslundia opposita (H. opposita), Aspilia africana* (*A. africana*) and *Solanum incanum* (*S. incanum*). The most cited plant for this purpose is *H. opposita* (108/108) followed by *C. floribunda* (100/108). Most of the plants in this category are herbs (4/5). All plants are obtained from wild habitats and aerial parts are used to perform the cleaning activity.

The plants were ranked according to order of preference during FGDs from the most preferred to the least preferred as *Hoslundia opposita (H. opposita), Conyza floribunda* (*C. floribunda*), *Monechma subsessile* (*M. subsessile*), *Aspilia africana* (*A. africana*) and *Solanum incanum* (*S. incanum*) respectively. *Hoslundia opposita* was ranked best because it has a nice smell, is readily available and is soft. *Conyza floribunda* and *M. subsessile* though ranked second and third respectively have similar characteristics of being soft, readily available and without a bad smell. *Aspilia africana* was ranked fourth because it has rough leaves which are required only when scrubbing new gourds. Nevertheless, these rough leaves do not leave particles in the *amakamo*. *Solanum incanum* was placed in the fifth position because it has rough leaves and hence it is used to scrub new gourds only. However, the use of *S. incanum* is slowly being discouraged because its leaves have hairy particles that remain in the *amakamo* thereby causing the consumers to cough.

Table 4

Plants used to clean and scrub vessels during amakamo processing

SN	Scientific and vernacular name	Family name and voucher number	Life-form	Part used	Citation frequency
1	*Monechma subsessile* (Oliv.) C.B Clarke (*Erazi)*	Acanthaceae (GN01)	herb	Aerial	95
2	*Aspilia africana* (Pers.) C. D. Adams (*ikarwe*)	Asteraceae (GN04)	herb	aerial	90
3	*Conyza floribunda* H. B. K. (*ametemalungi)*	Asteraceae (GN05)	herb	aerial	100
4	*Hoslundia opposita* Vahl, *(esitimwe)*	Lamiaceae (GN09)	shrub	aerial	108
5	*Solanum incanum* Linnaeus (*ebitobotobo)*	Solanaceae (GN17)	herb	aerial	80

During FGDs, these plants were also ranked according to order of preference from the most preferred to the least preferred as *C. molle*, *R. natalensis*, *G. ternifolia*, *E. divinorum* and *M. heterophylla* respectively. *Combretum molle* was the most preferred because it imparts a nice flavour to the *amakamo*. In addition, *C. molle* is universal because it can be used to smoke vessels for making *amakamo* (*ebirere*) and *amashita* (*ebishaabo*) thereby allowing the processor to use one plant for both products. Although *C. molle* is very rare in the study area, the processors buy it from hawkers, who get them from other districts. In the second position was *R. natalensis*, which is readily available in the area with relatively nice flavour though not equivalent to that of *C. molle*. This plant is not used to smoke the gourds for churning milk (*ebishaabo*) because it is alleged to cause emulsification of fats. *Gardenia ternifolia* came in the third position because it imparts a mild flavour to the *amakamo*. However, like *R. natalensis*, it is not used to smoke *ebishaabo* because it is claimed to melt the butter grains during churning. *Euclea divinorum* and *M. heterophylla* were in the fourth and fifth positions. These are rarely used despite being common in the study area. Moreover, *M. heterophylla* stem woods have thorns making them unfriendly to the users. For smoking drinking pots, only one plant is used, that is *Hyperrhenia filipendula* (*H. filipendula)* and hence was not ranked.

Table 5

Plants used to smoke fermentation and drinking vessels during amakamo processing

SN	Scientific and local name	Family name and voucher number	Life-form	Part used	Citation frequency
1	*Rhus natalenis* (Krauss) (*omusheshe)*	Anacardiaceae (GN03)	shrub	Stem wood	99
2	*Maytenus heterophylla (*Eckl. & Zeyh) Robson (*omuhwahwa)*	Celestraceae (GN06)	shrub	Stem wood	5
3	*Combretum molle* G. Don (*omurama)*	Combretaceae (GN07)	tree	Stem wood	108
4	*Euclea divinorum* Hiern, (*omushikizi)*	Ebenaceae (GN08)	shrub	Stem wood	60
5	*Gardenia ternifolia* Schumach. & Thonn. subsp. *jovis-tonantis, (entarama)*	Rubiaceae (GN15)	tree	Stem wood	90
6	*Hyparrhenia filipendula* (Hochst.) Stapf (*emburara)*	Poaceae (GN14)	grass	aerial	108

Preference of plants used as heat insulators, making starter culture and reconditioning fermentation vessels

Table 6 summarises the plants used as heat insulators, for making starter culture and reconditioning fermentation vessels. Two plants were used as heat insulators during milk fermentation. These were *Loudetia kagerensis* (*L. kagerensis*) and *Cymbopogon nardus* (*C. nardus*). Both of these plants are grasses whose aerial parts are dried to remove moisture and insects and laid down in the processing area (*orugyeegye*). These plants are both from the wild habitat and almost equally cited with *L. kagerensis* leading with 108 citations whereas *C. nardus* was at 106. In the FGDs, *L. kagerensis* was ranked best because it is readily available and easy to harvest whereas *C. nardus* was ranked second because it is rough, irritating and hard to uproot.

In the absence of samples for back slopping, new starter culture preparation is initiated by milk coagulation using extracts from certain plants. From this study, such plants include *Thunbergia alata* (*T. alata*), *Grewia mollis* (*G. mollis*) and *Citrus sinensis* (*C. sinensis*). *Thunbergia alata* and *G. mollis* are *shrubs* whereas *C. sinensis* is a tree. *Thunbergia alata* was cited by all respondents (108) followed by *G. mollis* (100). Both *T. alata* and *G. mollis* are from the wild habitat whereas *C. sinensis* is domesticated. Aerial parts, stem bark and fruit juice are the parts used for *T. alata*, *G. mollis* and *C. sinensis* respectively. During the FGDs, the plants were ranked according to the most preferred to the least preferred as *T. alata*, *G. mollis* and *C. sinensis* respectively. *Thunbergia alata* was preferred because it makes starter culture with good quality parameters. Because *G. mollis* imparts herbal flavor in the starter culture, it was ranked second whereas *C. sinensis* was ranked last because it causes the milk to form clots rapidly leading to increased souring.

In cases where *amakamo* with poor quality attributes is consistently obtained from a given fermentation vessel, the latter is treated with certain plants to restore its functionality. This is referred to as reconditioning. *Albizia coriaria* (*A. coriaria*) and *Erythrina abyssinica (E. abyssinica)* are the plants used to recondition fermentation vessels. Both of these plants are trees from the wild habitats whose stem barks are used for this purpose. Both of these plants were almost equally cited with *A. coriaria* at 108 and *E. abyssinica* at 105. In the FGDs, *A. coriaria* and *E. abyssinica* were ranked first and second, respectively. Fermentation vessels reconditioned with *A. coriaria* were said to produce good quality *amakamo*. In addition, *A. coriaria* is readily available in the study area and is easy to harvest unlike E. *abyssinica.*

Table 6

Plants used to provide insulation during fermentation, make starter culture and recondition fermentation vessels

SN	Scientific and vernacular name	Family name and voucher number, Role	Life-form	Part used	Citation frequency
1	*Cymbopogon nardus* (Franch.) Stapf (*omuteete)*	Poaceae (GN12) Insulation	Grass	aerial	106
2	*Loudetia kagerensis* (Schumach.) Hutch. (*eyozwe)*	Poaceae (GN13) Insulation	Grass	aerial	108
3	*Thunbergia alata* Bojer ex Sims (*wankura)*	Acanthaceae (GN02) Starter	Shrub	aerial	108
4	*Grewia mollis* Juss. (*omukoma)*	Tiliaceae (GN18) Starter	Shrub	Stem bark	100
5	*Citrus sinensis* (L.) Osbeck (*omuchungwa)*	Rutaceae (GN16) Starter	Tree	Fruit juice	95
6	*Albizia coriaria* Oliv. (*omusisa)*	Mimosoideae (GN10) Reconditioning	Tree	Stem bark	108
7	*Erythrina abyssinica* DC. (*ekiko)*	Papilionaceae (GN11) Reconditioning	Tree	Stem bark	105

Discussion

The drive towards recognising indigenous knowledge as being innovative and unique among cultures has contributed to socio-economic development in Sub-Saharan Africa (Hawaz *et al.*, 2025). Additionally, indigenous methods of food preparation have been proven feasible and useful by local communities for long (Akabanda, 2025). They are also known to contribute to food security, promote culture and local skills transfer in rural communities (Hawaz *et al.*, 2025). The pastoral communities in Kiruhura District hold unique and prestigious indigenous knowledge on preparation of *amakamo* that are worth documenting. Therefore, the current study sought to provide documentation, deep understanding of indigenous knowledge and practices involved in *amakamo* processing by Bahima communities in Kiruhura District of South-Western Uganda.

The higher percentage of women being involved in *amakamo* processing as compared to their male counterparts is comparable to findings in Ethiopia where milk processing and preservation were mainly performed by women (Gebeyew *et al.*, 2016). This is probably because food preparation is the role of the women and most of the respondents were also married. The fact that most respondents had a lot of experience in processing *amakamo* despite being young could probably be because the girls learnt the skill of *amakamo* processing by getting involved in the activity as early as possible. This is further evidenced by the age bracket of 31 to 40 years dominating the respondents, which clearly shows that many attained the knowledge of *amakamo* processing before the adult age of 18 years. Knowledge about *amakamo* being transferred to young generations mainly by parents is comparable to previous reports, which show that African indigenous knowledge transfer systems are through oral conversation mainly from parents and guardians (Dlamini, 2024).

The fact that *amakamo* was processed daily by majority of the respondents is likely because the communities consume this product throughout the day. Moreover, it is also majorly processed for home consumption, which further confirms the significance of this beverage in the culture of Bahima. The finding that most processors preferred to use milk from their own farms could be because the processors wanted to start with milk whose quality they were sure of to avoid product failure and safety concerns. Previous reports about fermented milk products processing have also shown that presence of contaminants, adulterants and drug residues in milk affect the activity of the starter culture organisms thereby prolonging the fermentation time (Chiesa *et al.*, 2020). The preference to use milk from local cows by most *amakamo* processors is similar to a previous finding on processed *ergo,* a fermented milk product from Ethiopia, whose processors had preference for milk from local cows as reported by Negash *et al.* (2012). This finding could be explained by the fact that local cattle breeds have higher butter fat and hence yield more cream that can be channeled into processing of other products like traditional butter, *amashita* (Hawaz *et al.*, 2025).

The findings revealed that two categories of vessels were used during *amakamo* processing in Kiruhura District. The community preferred traditional vessels since they were claimed to give rise to *amakamo* with better flavour and shelf life as compared to their modern counterparts. The use of traditional vessels during fermentation of milk products in the community under study does not differ from what was reported in previous studies for production of *ergo* (Gebeyew *et al.*, 2016), *urubu* (Nzigamasabo and Nimpagaritse, 2009), *kivuguto* (Karenzi *et al.*, 2013), *mabisi* (Moonga *et al.*, 2019) and *mursik* (Nduko *et al.*, 2017). Since traditional vessels are obtained from natural raw materials such as plants, there is a need for their conservation to be prioritized.

The major steps involved in *amakamo* processing namely: cream separation, boiling, cooling, back slopping, fermentation and curd breaking are similar to those reported by several African indigenous communities. Previous studies reported similar steps during preparation of k*ivuguto* in Rwanda (Karenzi *et al.*, 2013), *urubu* in Burundi (Nzigamasabo and Nimpagaritse, 2009), *kule naoto* and *amabere amaruranu* in Kenya (Mathara *et al.*, 2004; Nyambane *et al.*, 2014). However, during the production of *bongo* by the Itesots (Gulaita, 2015) and *mabisi* by the Tonga of Zambia (Moonga *et al.*, 2019), there is no backslopping, but rather spontaneous fermentation. Remarkably, most of the steps involved in *amakamo* processing can be supported scientifically giving basis for its future standardization. Cream separation helps to reduce the level of fat in *amakamo* since it would be very disastrous if whole milk was used to make the product as it would predispose the consumers to cardiovascular diseases (Enahoro *et al.*, 2018). Additionally, fat in cream may contribute to lipid peroxidation that can lead to off-flavours of the resultant product. Boiling milk kills pathogenic organisms, reduces the levels of spoilage types and denatures whey proteins thereby contributing to the good textural properties of fermented milk products (Lee and Lucey, 2010). Cooling of milk to lukewarm temperature provides an optimum growth environment for the microorganisms in the starter inoculum to multiply since some fermentative organisms require mesophilic conditions for optimum growth (Agyei *et al.*, 2020). Backslopping helps to accelerate the fermentation process, produces lactic acid that leads to reduction in pH, contributing to more denaturation of whey proteins and improving viscosity of *amakamo* (Guan *et al.*, 2025).

The major causes of *amakamo* processing failure which include the type of plants used for smoking the fermentation vessels and the poor-quality starter cultures have been documented before (Owusu-Kwarteng *et al.*, 2020). A previous study in Rwanda on *kivuguto*, a fermented milk product similar to *amakamo* reported that the type of plants used to smoke fermentation vessels contributed to better product quality characteristics such as firm curd, solid texture and smoky flavour desired by the consumers (Karenzi *et al.*, 2013). It is likely that *amakamo* and *kivuguto* are similar since the two communities seem to be more related and may have a common ancestor from whom the practice was passed. Earlier studies carried out to evaluate the role of smoked vessels in milk processing found out that they contribute to slowing down of the acidification process and reduce the coliform numbers thereby increasing the shelf-life of the final product (Owusu-Kwarteng *et al.*, 2020). Starter cultures have also been documented to be very key in kick-starting the fermentation process and if poor starters are used, it may lead to quality defects such as wheying-off (Shekhar, 2024).

The commonest signs of defects arising out of poor processing of *amakamo* recorded in this study include milk separation and sourness. Milk separation also known as wheying-off is due to factors such as milk adulterated with water which leads to reduction in milk total solids (Lee and Lucey, 2010). This further retaliates the reason why processors preferred to use milk from their own farms for making *amakamo*. This helps the farmers to avoid losses due to adulterated milk.

Sourness of *amakamo* may be as a result of post-acidification which occurs due to continued lactic acid production (Shekhar, 2024).

Much as the Poaceae family registered the highest number of plants in this study, they did not rank highly in *amakamo* processing save for *H. filipendula* which was used to smoke the milk pots (*ebyanzi*). The rest were used as heat insulators during fermentation. The fact that most of the cited plants were shrubs is of an advantage since these can easily be propagated because they take a shorter time to mature, which contributes to faster conservation. The practice of using aerial parts as cited by most of the respondents poses a threat to their conservation since these plants may not easily rejuvenate after their harvest. This calls for scientific studies to establish the most useful parts so as to reserve the remaining ones for future rejuvenation and consequent conservation.

Furthermore, almost all of the plants were obtained from the wild, which is a threat to the conservation of both the knowledge and the plants that may become extinct before they are fully studied. Wild vegetation is prone to being destroyed due to urbanization pressures, agriculture and industrialization (Dlamini, 2024). Efforts should therefore be put in place to sensitize the communities on the importance of domesticating the plants used during *amakamo* processing. It is worth noting that the community has already started facing challenges related to some of the important plants in *amakamo* processing becoming rare for example *C. molle* as lamented by the respondents in the FGDs.

The plants used to scrub vessels in this study differ from those which were documented in earlier studies carried in out Ethiopia, where *Ocimum hardiense*, *Croton macrostachyus* and *Sida cuneifolia* were used for this purpose (Mekonnen and Lemma, 2011). The plants used to smoke fermentation vessels are different from those reported in earlier studies carried out in Ethiopia which included *Olea africana, Juniperous procera, Croton macrostachyus, Stephaia abyssinica, Eucalyptus globulus, Arundinaria volkensii, Capparis tumentosa, Dodonaena angustifolia, Dracaena afromontana, Ocimum hardiense, Ocimum santum, Premna resinosa, Schefflera abyssinica, Solanum nigrum,* and *Syzygium guieense* as reported by Mekonnen and Lemma (2011), Negash *et al.* (2012) and Gebeyew *et al.* (2016). However, the use *C. molle* to smoke gourds seems to cut across most communities practicing traditional milk fermentation in East Africa. Additionally, *H. filipendula* has also been documented in a study carried on *kivuguto* in Rwanda to play a role in smoking drinking pots (Karenzi *et al.*, 2013). The fact that all the mentioned studies are in East Africa shows that some of the cultural attributes regarding milk processing cut across the indigenous communities, which can contribute to easy acceptability of the *amakamo* product and transferability of the associated skills.

Under modern milk processing technologies, there is a mechanism for maintaining temperature throughout the fermentation period. This helps to maintain the activity of the lactic acid bacteria used as starter cultures. It is often difficult to maintain incubation temperature under traditional milk processing technologies (Moonga *et al.*, 2021). The plants used for conserving heat during fermentation namely; *L. kagerensis* and *C. nardus* seem to act as insulators since they are poor conductors of heat. This prevents conduction of heat from the fermentation vessel to the surrounding. In so doing, the lukewarm temperature of the milk is maintained throughout the fermentation period which helps the starter organisms to work optimally.

The finding that plants such as *T. alata*, *G. mollis* and *C. sinensis* were used to make starter culture can be explained by the fact that some bacteria that are used as LAB for example *L. plantarum*, *L. florum* and *Fructobacillus* have been recovered from plant surfaces and in fermented plant products (Andreson *et al.*, 2024; Mikołajczuk-Szczyrba *et al.*, 2025). Previous research showed that plant extracts from oats and peas obtained through maceration helped in evolution of lactic acid bacteria through series of backslopping cycles (Andreson *et al.*, 2024). These LAB were used as starter cultures in the production of non-dairy fermented beverages. Therefore the use of plant extracts to make starter is plausible. However, further research is required to study the quality of the resultant *amakamo*.

The process the fermentation vessels undergo before they are ready for use is very tedious. Therefore, all effort geared towards ensuring their continued use is vital. According to the processors, reconditioning of fermentation vessels is recommended when the milk takes unnecessarily long time to form the curd and when there is a lot of gas formation (*bwagga*) in the *amakamo*. Milk is known to form biofilms which may stick on the fermentation vessels (Cruciata *et al.*, 2018). According to Banda *et al.* (2020), biofilms are resistant to common cleaning and sanitation treatments. It is possible that these vessels accumulate spoilage microorganisms whose population may not be controlled by the lactic acid bacteria. The two plant species used for reconditioning the fermentation vessels that is *A. coriaria* and *E. abyssinica* have been shown to have antimicrobial activities (Obakiro *et al.*, 2021; Omara *et al.*, 2023). It is possible that the phytochemicals in these two plants contribute to removal of the biofilms in the fermentation vessels. However, the use of plant extracts to recondition the fermentation vessels warrantees further investigation.

Conclusion

The study concludes that *amakamo* is a creamish-white fermented milk product processed from low-fat milk that is boiled, cooled and inoculated with previous *amakamo* through a process of back slopping. The vessels used during the processing of *amakamo* are smoked using several plants and that the type of plant used to smoke the fermentation has a very big impact on the quality of the resultant *amakamo*. However, most of the plants used for this activity are obtained from the wild habitat which poses a risk of being lost due to urbanization pressures. Furthermore, many of the plants have not been reported before during milk processing making this aspect unique to *amakamo* production.

Recommendations

Since the plants are very key in *amakamo* processing, the locals need to be sensitized about sustainable use of these plants and where possible, encourage their domestication. The study recommends that further studies be done to investigate the phytochemical composition of plants used to smoke fermentation vessels and how they affect the quality of the resultant *amakamo.* Further studies need also to be carried out to determine the composition of smoke to see if a smoke product can be generated from the woods and standardized for local use.

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Availability of data

The data used to support the findings of this study are available from the corresponding author upon request.

Conflict of interest

Authors declare no competing interest.

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