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The possible impact of precooling and community cooling hubs on reducing post-harvest losses in hibiscus farming: A case study from Uganda.

Mary NAJJUMA*[(a)], Robin CAMPBELL[(a)], Alan FOSTER[(a)], Catarina A. MARQUES[(a)], Graeme MAIDMENT[(a)], Judith EVANS[(a)]

[(a)] London South Bank University
London, SE1 0AA, United Kingdom
* najjumam@lsbu.ac.uk

ABSTRACT

This study addresses the significant post-harvest losses in hibiscus farming in Uganda's Central and Eastern regions, impacting the local economy and culture. Research involving 200 farmers shows losses of 10% to 50%, particularly during the wet season due to poor storage and drying facilities. To combat this, the study proposed a three-pronged approach: ensuring gentle handling during harvest, implementing precooling techniques at the farmgate, and establishing community cooling hubs. Precooling is crucial for maintaining post-harvest quality by rapidly reducing temperatures, while community cooling hubs would offer centralized cooling and storage, mitigating losses and opening new market opportunities. This comprehensive strategy also aims to enhance agricultural practices through training, capacity building, and community collaboration, promoting a resilient and thriving farming community.

Keywords: Hibiscus, post-harvest losses, precooling, cooling hubs, rural farming communities

1. INTRODUCTION

In Uganda, particularly in its Central and Eastern regions, hibiscus farming is becoming a significant agricultural practice, known for its striking flowers and diverse uses in nutrition and medicine to boost immunity, lower high blood pressure, relief from menstrual pain and as an antioxidant and anti-depressant (Jeffery and Richardson, 2021). This crop is integral to the local economy and cultural practices in these regions. The hibiscus farmers in these two areas are organized in collective groups of 200 members of which 70% are women. On an average day during the harvest season, they gather about 3 tonnes of fresh hibiscus calyces per region. Their primary market outlet is Rena Beverages Limited, a private agro-processing firm specializing in organic beverages, teas, coffee, and spices. This company partners with out-grower farmer collectives in various Ugandan regions to organically cultivate hibiscus and other crops.

A study involving 200 hibiscus farmers from Tororo hibiscus out-growers farmer group highlighted the gravity of the issue of post-harvest losses. The findings reveal substantial post-harvest losses, ranging from 10% to 50% in normal conditions, which can escalate to complete harvest loss during the wet season due to the lack of proper storage and drying facilities. These losses significantly impact the economic stability and well-being of the farmers and their communities, leading to reduced income. The primary issue with hibiscus farming is the heat-induced quality deterioration after harvest, a problem that remains even when harvesting is done at the optimal maturity. The wet season further aggravates this issue, underscoring the need for effective post-harvest management strategies.

To address these challenges, this paper proposes a three-fold approach: gentle handling using the right tools for harvesting; implementing precooling techniques at the farmgate; and establishing community cooling hubs. Precooling at the farmgate plays a vital role in preserving the quality of hibiscus immediately after harvest. This process involves rapidly lowering the calyces' temperature, which significantly slows deterioration. This method is particularly critical during the wet season when conditions favour rapid spoilage.

Beyond individual precooling techniques, this paper advocates the need for the creation of community cooling hubs. These hubs are envisioned as centralized facilities where farmers, including those growing other small-scale fruits and vegetables, can access cooling and storage services. This collaborative approach not only provides a practical solution to post-harvest losses but also opens new market opportunities by ensuring that the produce reaches buyers in optimal condition. The establishment of community cooling hubs is more than a technological solution; it represents a holistic approach to agricultural development. This initiative includes training, capacity building, and the formation of a supportive community network, aiming to bring about positive changes in agricultural practices in the region. Such developments are expected to foster a more resilient and prosperous farming community.

2. LITERATURE REVIEW: HIBISCUS, A VITAL PLANT

There are over 300 species of hibiscus found across tropical and subtropical areas globally. While most species of hibiscus are cultivated for ornamental purposes, several are also recognized for their potential medicinal benefits (Qi *et al.,* 2005). According to a field extension researcher, only six species are known to be grown in Uganda. Notable examples are Hibiscus sabdariffa widely known as "red sorrel" and "roselle" and H. cannabinus (Kenaf), known for its fibre, as well as H. esculentus (okra or ladyfinger), which is consumed as a vegetable. The edible parts of the plant include dried calyces and corollas, which are harvested and marketed either as whole or cut dried calyces, commonly referred to as hibiscus blossoms. Hibiscus tea, also known as malvern tea, is noted for its pleasantly tart flavour, attributable to an acid content of 15-30%, including citric, malic, tartaric acid, and hibiscin. The tea's distinctive wine-red colour is due to its anthocyanin content, which is approximately 1.5% (Augstburger *et al.,* 2000). The focus in this report is on the roselle which is grown for its economic interest of the calyces in Uganda.

Figure 1: Roselle calyces- (©Moses Omullo)

Figure 2: Kenaf plant (© Rob Lumen Captum | Dreamstime.com)

Hibiscus is composed of a variety of compounds such as quercetin, glycoside, riboflavin, niacin, carotene, anthocyanin, anthocyanidin, malvalic acid, gentisic acid, margaric acid, and lauric acid. These components contribute to its wide range of claimed medicinal properties. It is known for its anti-nociceptive and anti-inflammatory effects, as well as its potential in treating convulsions, ulcers, diabetes, fever, and wounds. Additionally, it promotes hair growth and has antibacterial, anti-cancer, and immunomodulatory qualities. Hibiscus rosa-sinensis is also recognized as an aphrodisiac and has claimed neurobehavioral, antioxidant, neuroprotective, cardioprotective, hepatoprotective, lipid-lowering, antidepressant, and antihypertensive effects, showcasing its considerable pharmacological potential.

Producing high-quality hibiscus calyces in developing countries is increasingly crucial for adding value and generating income, benefiting rural communities. Yet, there is a noticeable gap in available literature concerning the effective quality evaluation and enhancement of these calyces. This includes aspects such as cleanliness and the levels of active ingredients, which are often overlooked in existing commercial standards (Juliani *et al.,* 2009).

In Uganda, hibiscus is grown biennially and harvested between May to September and November to January. The timing of the harvest is crucial and is based on the maturity of the seeds. The fleshy calyces are collected post-flowering, but before the seedpod dries and opens. The longer the capsule stays on the plant after seed ripening begins, the higher the risk of the calyx developing sores, sun cracking, and overall quality degradation (Plotto, 2004). However, harvesting is exclusively manual.

Figure 3: Farmers and extension researchers at a mature garden in Buikwe, central Uganda (© Rena Beverages Ltd)

Figure 4: Farmers being trained about proper harvesting techniques (© Rena Beverages Ltd)

3. METHODOLOGY

The primary approach for gathering data in this study was through qualitative methods. Data collection involved creating questionnaires and conducting observations and interviews with 20 key individuals: managing director of Rena beverages Limited, the chairperson of the Tororo Hibiscus Out-growers Farmer Group, a field extension researcher, and several of the farmers themselves. The choice of the Tororo group, facilitated by Rena Beverages Limited, was influenced by its unique organizational structure. This group comprises 200 active members who cultivate hibiscus as their primary crop, in addition to various horticultural products for both personal use and commercial sale. The farmer group has a collection centre located about 2-10 kilometres from the farmers with a sorting area, harvester and pipes for shelling, traditional solar dryers and a direct sun drying area.

Figure 5: Farmers sorting, washing and preparing to use harvester for shelling (©Moses Omullo)

Figure 6: Traditional solar dryers (©Moses Omullo)

Observations required getting involved in a farmer's daily routine during harvesting and post-harvest. This entailed accompanying the farmers to the garden at 6 am for harvesting. Hibiscus harvesting involved manual plucking of each calyx using knives, placed in baskets and basins, then transferred to sacks once the containers were full. Typically, each field had two harvesters, predominantly relying on family labour. Harvesting activities began early, around 6 am, to avoid the heat of the sun, and concluded by midday. Post-harvest, for the harvest, which was not going to the collection centre, the calyces were promptly laid out on tarpaulins for sun-drying, a step crucial to preventing mould and fungal infections.

The interview questions included questions ranging from the average harvest per day, losses at farmgate and collection centre, preservation methods, price of dry calyces, means of transport to the collection centre, capacity of solar dryer and benefits from hibiscus farming. The interviews with the extension researcher and Rena beverages were held on phone whereas, those with the out-growers were in-person.

4. RESULTS AND DISCUSSION OF FINDINGS

The interview conducted with the extension researcher revealed that while the standard hibiscus farm size is around two acres in the Tororo region, some Central Ugandan farmers have significantly expanded, managing 10 to 30 acres for commercial production. The average yield was estimated to be around 100 kg per acre. However, farmers reported substantial losses: 30-50% at the farmgate and around 10% at the collection centre, predominantly influenced by varying weather conditions.

Through observation and from the interviews with the farmers, several challenges were identified such as inefficient harvesting equipment, relying on bare hands and knives to pluck each hibiscus calyx. This method poses safety risks due to the hibiscus stalks' hairy nature and the potential for cuts from the knives. Furthermore, this slow harvesting process often results in calyces maturing beyond their optimal stage, leading to a decline in quality.

The predominant preservation technique is direct sun drying, chosen mainly because of the limited capacity of the solar dryer and its high demand among farmers. This dryer is not exclusively used for hibiscus but also for drying other produce such as mangoes, bananas, and pineapples. At the farm level, the harvested calyces are laid out on tarpaulins directly on the ground, exposing them to risks of contamination from dust and bird droppings, and the varying intensity of sunlight further affects the quality of the dried calyces.

The traditional solar dryers at the collection centre rely solely on solar radiation. Hibiscus calyces are transported to this centre in sacks, primarily on bicycles and motorcycles. Once these calyces arrive, they undergo a process of sorting and shelling which is extracting seeds with the aid of hand harvester pipes and a motorized harvester sponsored by Rena beverages. This method is most effective when the calyces are freshly harvested with a high moisture content. The solar dryer, designed to hold up to half a tonne, can reduce the moisture content of the calyces to below 12% within 3-4 days. It maintains regulated temperature and humidity levels, ensuring uniform drying while preserving the quality of the calyces. Any additional calyces that exceed the dryer's capacity are spread out on tarpaulins under the sun, to prevent mould and fungal infestations, as well as to reduce contamination risks. To use the dryer, farmers must reserve a slot at the collection centre and pay a fee of US $0.1 per kilogram. Notably, the collection centre does not have cooling facilities.

The capacity of the sun dryer at the collection centre is insufficient to meet the needs of all the farmers. Calyces dried in the solar dryer are of superior quality, yielding approximately three times more income than those dried under direct sunlight at the farmgate. Additionally, the drying section at the centre is not adequately sized to handle the volume of harvest from all the farmers. The price of the dried calyces using the solar dryer is approximately US $1.25 compared to US $0.4 at the farmgate.

In an experimental trial, one of the farmers who had reserved a slot at the solar dryer altered their post-harvest process. Following the day's harvest of 50kg, the calyces, instead of being directly sent to the centre, underwent a different procedure. The calyces were first sorted, then submerged in cool water to reduce their field heat, followed by washing, and subsequently placed into crates. The water used was got from a nearby well, cooled to an approximate temperature of 10^{o}C using ice brought from Kampala. The calyces were submerged for at least 1 hour to a temperature of about 13^{o}C before being transferred to the crates. This acted as our seven eighth cooling time and temperature respectively. The crates were then covered with moist blankets for transport to the centre, a distance of 10km. Upon arrival, the calyces were still fresh and therefor eased the shelling process prior to being placed in solar dryer. Notably, this process resulted in no losses from the initial 50kg. The application of hydrocooling to reduce field heat not only kept the calyces fresh upon arrival at the centre, facilitating an easier shelling process, but it also ensured they were clean.

After 3 days in the solar dryer, Rena beverages reported that the output was of much better quality compared to the rest.

4.1. Causes of loss during and post-harvest

The manual and labour-intensive nature of the hibiscus calyx harvesting process, compounded by the limited workforce and inadequate tools, results in an inability to harvest the entire crop within its peak maturity period. This inefficiency leads to a portion of the produce remaining unharvested and ultimately lost.

Hibiscus is typically sold in a dried form, and during the rainy season, the absence of sufficient solar radiation can significantly increase losses due to the inability to properly dry the calyces. This inadequate drying can lead to the calyces developing mould and rotting. Farmers who rely on sun drying at their farms can face up to 100% losses in such conditions, as the calyces fail to dry effectively. On the other hand, at collection centres equipped with solar dryers, the losses might be limited to about 50%, although the drying process is prolonged more than usual due to reduced solar intensity.

While sun drying hibiscus calyces is a common traditional technique, it is not the most effective method for preserving their quality, particularly in terms of retaining their antioxidant content. The process of drying the petals under direct sunlight can diminish their antioxidant capacity. This decrease is primarily due to the high temperatures involved in sun drying, which can lead to significant losses of antioxidants like ascorbic acid, flavonoids, and phenolic acids. The high temperature causes these compounds to oxidize, thereby reducing the calyces' antioxidant potential (Marnoto, 2014).

Furthermore, drying hibiscus petals in the open-air subjects them to contamination from environmental elements such as cosmic dust, which might carry harmful microorganisms like viruses and bacteria. This exposure compromises the hygienic quality of the dried petals. The traditional method of open sun drying, often used by rural farmers, also has several drawbacks. It can result in substantial crop losses due to insufficient drying, leading to problems like fungal attacks, and the encroachment of insects, birds, rodents, and damage from unpredictable rain and other weather-related factors (Gomaa and Rashed, 2016). This results in lower prices paid for the dried calyces due to the low quality.

During periods when the supply of hibiscus exceeds demand, farmers often choose not to harvest the mature calyces, leaving them in the field. This decision helps them save on the costs associated with labour during both the harvest and post-harvest periods. This situation reflects the challenges in managing the harvest and post-harvest processes, particularly in balancing the costs of labour and the need to maintain the quality of the hibiscus calyces.

4.2. Benefits of cooling for the farmer groups

Precooling is the process of quickly reducing the temperature of a crop after harvest to remove field heat. Field heat is the temperature difference between the crop at harvest and its optimal storage temperature. Generally, the goal is to lower the temperature to at least 75% of the difference between its current temperature and the ideal storage temperature. This rapid cooling is vital because even a one-hour delay in cooling under field conditions of about 35°C can result in a day's loss of shelf-life, even if the produce is later stored optimally (Kanade, O.J and Vishwakarma,2019). Most used precooling methods include for hydrocooling, forced-air cooling, vacuum cooling, water spray, ice and room cooling.

From the experimental trial, hydrocooling was applied at the farmgate and the low temperatures were maintained using a moist blanket during transportation. The calyces were delivered with a high moist content which eased the shelling process and maintained a superior quality of the dry product. As noted earlier, from this trial the farmer earned three times more from the sale of the dried product. Precooling contributed to maintaining the freshness of the calyces thus preserving their quality and the solar dryer provides a conducive environment. This would greatly boost the farmers income when applied.

Though, no experimental trial was conducted for cooling hubs, however, the chairperson of the out-growers farmer group strongly suggested that its establishment could greatly impact the lives of the farmers. The solar dryer's capacity is limited and there's a necessity to preserve the excess calyces delivered daily by farmers. A cooling hub at the collection centre would play a crucial role in reducing losses and maintaining the quality of these products. As farmers cultivate hibiscus for income alongside other horticultural products for consumption and sale, this hub can be used for other products as well especially during off-season production. At the collection centre, various products are gathered for distribution, including to markets up to 200 kilometres away, like Kampala city centre. Thus, a cooling hub would be a sustainable, year-round investment benefiting the entire community.

It was noted that the dried hibiscus sold at farmgate achieved 50- 75% lower income than that sold at the collection centre dried using the solar drier.

The cooling hub would be designed to include areas for sorting, cleaning, and packaging, precooling and cold storage. By utilizing current refrigeration technologies that employ natural refrigerants, solar energy, and thermal storage, and providing training on operating a cooling hub, farmers would be positioned to achieve economic gains. This approach aims to minimize losses at the collection centre while maintaining the quality of the products for a sustainable market supply and increased incomes.

1. CONCLUSIONS

Though there are limited detailed studies conducted on hibiscus especially in quality, this study on hibiscus farming in Uganda's Central and Eastern regions reveals its growing importance in agriculture, offering significant nutritional and medicinal benefits. However, the study uncovers substantial post-harvest losses, primarily due to inefficient harvesting methods and inadequate storage and drying facilities, leading to reduced income for farmers. The proposed solutions, including improved harvesting techniques, precooling methods, and the establishment of community cooling hubs, aim to enhance the quality and market value of hibiscus, potentially increasing farmers' earnings. Despite these insights, the study faces limitations, such as its focus on specific regions and reliance on a particular farmer group, which might not represent the entire hibiscus farming community in Uganda. Methodologically, the emphasis on qualitative data limits the scope for quantitative analysis.

For future research, there is a need for further investigation into alternative post-harvest technologies which are low-cost and scalable to rural areas with no grid access, along with an in-depth economic feasibility study of the cooling hubs including funding models for technology implementation. Additionally, research should extend to understanding the environmental impact of these technologies and the socio-cultural dynamics influencing farming practices. Understanding the influence of climate change on hibiscus farming and exploring the global market dynamics for hibiscus products could provide crucial insights for developing effective strategies to boost the crop's economic potential in Uganda and similar contexts.

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