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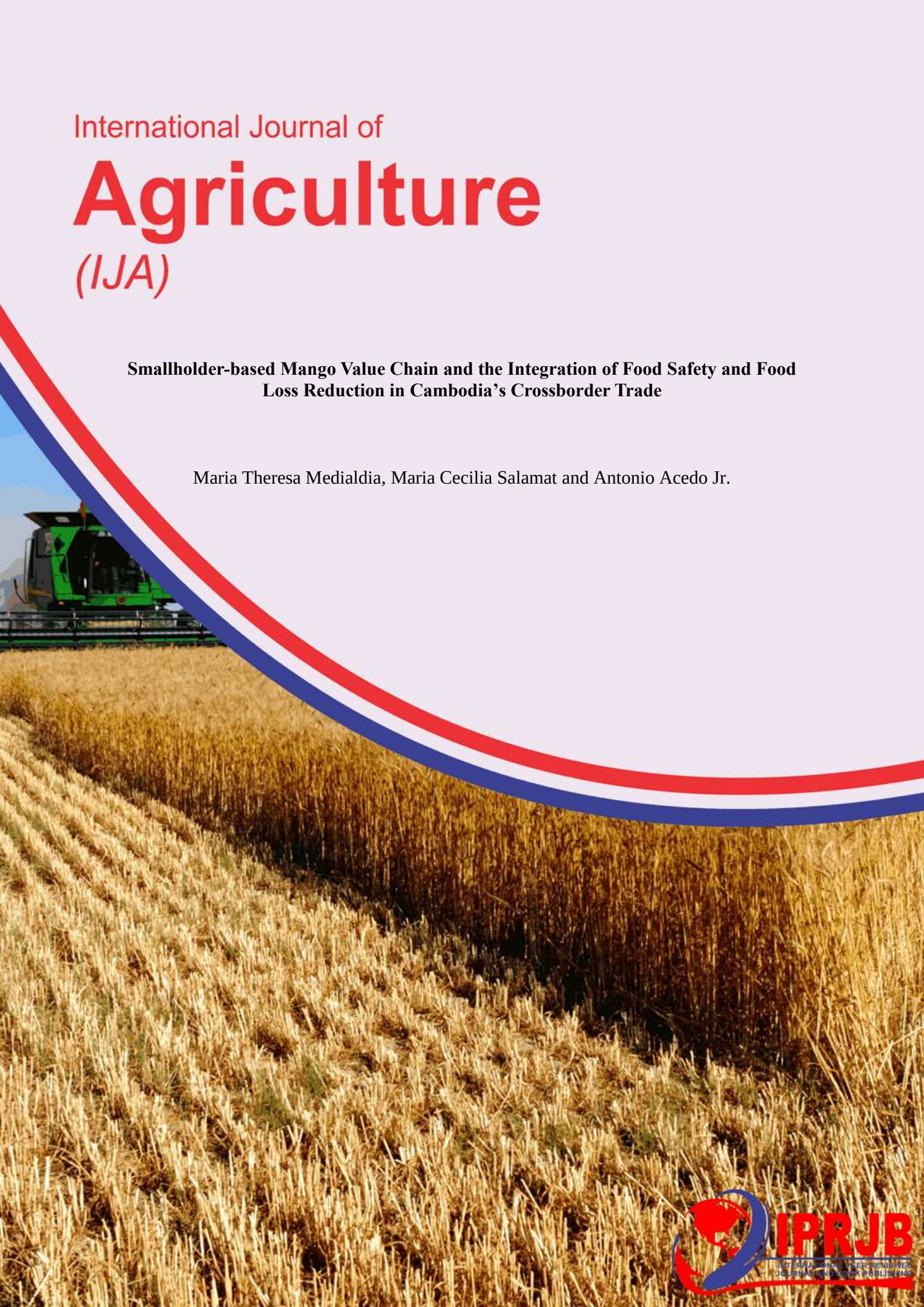

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[1]Maria Theresa Medialdia, [2]Maria Cecilia Salamat and [3]Antonio Acedo Jr.
[1]Mekong Institute, Khon Kaen, Thailand
[2]Central Bicol State University of Agriculture, Camarines Sur, Philippines
[3]University of the Philippines Los Banos, Laguna, Philippines

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Abstract

Purpose: The study mapped the smallholder-based crossborder mango value chain in Cambodia; assess the practices and problems particularly in relation to food safety and food loss, and recommend future actions.

Methodology: Secondary and primary research was conducted through desktop review of literatures, focus group discussions and key informant interviews to document the crossborder value chain and the practices and problems of smallholder mango producers who are compliant and non-compliant to Cambodia Good Agricultural Practice (CamGAP). Descriptive analysis of results is presented.

Findings: Mango is grown in all Cambodia's provinces, with about 60% in Kampong Speu and over 80% is Keo Romeat variety. From 2016-2020, production and export increased tremendously. However, unrecorded informal crossborder trade is about ten times of official record, estimated at over 945,000 tons in 2020. The value chain starts from input supply through production, postharvest and transport to crossborder market destinations in Vietnam, Thailand and China. About 80% of mango producers are smallholders and majority are non-CamGAP compliant. The practices of CamGAP-compliant and non-compliant farmers differed. CamGAP mainstreams both food safety and food loss management. Conventional farmers essentially employ chemical agriculture. Fruit losses during production and postharvest are much higher for conventional producers than CamGAP producers. Major factors contributing to fruit losses and food safety problems include lack of capital for production and postharvest inputs, deficiencies in production and postharvest practices and facilities, limited adoption of food safety management systems (FSMS) (e.g. GAP, GMP and HACCP), cumbersome certification systems including export processing, and limited access of farmers to export markets as intermediaries have big role in crossborder trade.

Unique Contribution to Theory, Practice and Policy: Improving value chains requires primary and support activities to add value and/or reduce cost, which could be achieved through managing food safety and food loss. The results of this study show that FSMS adoption, as in the case of CamGAP mango producers, could reduce food loss and harness the food safety system to increase market access. However, capital, knowhow and market support are also crucial. National policies and actions should promote the wide adoption of CamGAP and other FSMS tools such as GMP and HACCP; increase access to financial products; facilitate market access including incentive system to reduce the informality of crossborder mango trade; and capacitate smallholders to enable them to competitively engage with crossborder value chain and international market.

Keywords: *Mangifera indica, Value Chain Mapping, Food Safety-Food Loss Nexus*

JEL Codes of Classification: O0, O3, Q1, Q13, Q17, Q18

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INTRODUCTION

Mango is Cambodia's second most important fruit crop after banana and a strategic agricultural product for export (RGC, 2019a; Piseth et al., 2021). It is a national priority crop as embedded in the Agriculture Sector Development Program 2018-2023 and Crop Master Plan 2030, which aim to transform Cambodia's mango industry into one of the five major exporters of quality fresh fruits in the world (Goletti & Sin, 2016; MAFF, 2017). Mango is grown all over the country, with Keo Romeat as the most popular variety for both domestic and export markets, accounting for about 80% of total mango production (Meng, 2021). Keo Romeat fruits are green outside and golden yellow inside at harvest and when the fruit ripens, the skin becomes yellow with deep yellow flesh, and it has low to medium fibrosity, high sweetness, and aromatic flavor. The fruit can be consumed green or ripe. It has become popular for export markets especially Thailand and Vietnam which share border with Cambodia. Mango production increased massively from 5,048 ha in 2016 to 137,950 ha in 2020 yielding 1,495,989 tons of fruit. Of the total planted area, 3,421 ha is owned by large companies; thus, mango production is dominated by smallholders. Smallholders are often excluded from value chain transformations that increase access to high-value export markets which demand consistent supply of safer and better-quality products. This is because of the high risk and costs of dealing with a large number of heterogeneous small producers and the inabilities of smallholders to meet product standards and other market requirements due to lack of necessary skills, technology, financing, and infrastructure. Most farmers have no control over when the mangoes leave their farms, and because of underdeveloped postharvest and marketing infrastructures and weakly organized supply chains, value-added activities such as grading, packaging, and processing are done in Vietnam or Thailand (Goletti & Sin, 2016; Hickey, 2019). This has contributed to the pervasive informality of crossborder trade of Cambodian mango.

Food safety and food loss add pressures on value chains. Food safety limits the opportunities of smallholders due to the requirements for new knowledge about food safety, additional investment in equipment and food safety systems, and more intensive linkages between producers and buyers. On the other hand, food loss makes agrifood systems less efficient and sustainable. When food is lost, the land, water, and other inputs used to produce it are wasted. The magnitude and causes of food loss are different for every crop and every location or value chain, so preventing it is context-specific. For example, in the trade of perishable produce between Vietnam and China, as much as 40% of produce is rejected or downgraded due to deficiencies in transport (GIZ, 2014). For Cambodia mangoes, a range of factors contribute to reduced quality outturn at distant markets. If fruit-protection covers were not used, about 5% of fruit suffered defects from pests and 50% of fruit have dark skin which decreases fruit color quality (Som, 2019). Harvesting early in the season decreases dry matter content and sweetness at the ripe stage, while delaying harvesting results in reduced fruit shelf life due to quick ripening and softening. The common practice of packing fruits in 20-kg plastic bags or 40-kg plastic crates and stacking them on top of each other during transport could exacerbate fruit losses. Furthermore, mangoes from smallholder producers do not often meet quality and size requirements of export (CPSA, 2020). Cambodia's mango shipments have been routinely blocked before making it to the international market, as the mangoes are not of high quality to meet sanitary and phytosanitary requirements (RGC, 2019a).

Given the scale of the food loss and food safety problem and the potential to bring about change, including greater economic, social, and environmental benefits, it is imperative to integrate food safety and food loss considerations in agrifood value chains. Developing value

chains that are smallholder-inclusive could increase the participation of smallholders in high-value markets (Permani et al., 2015; FAO, 2017). Value chains require primary activities to create value and/or reduce cost of the product and support activities (e.g. procurement, technology, manpower and infrastructure systems) to achieve competitive advantage (Inchainge, 2023). A universal first step in improving value chains is baselining or diagnostics which informs suitable interventions. This study was conducted to map the Keo Romeat mango crossborder value chain, assess value chain practices and problems, particularly those related to food safety and food loss, and recommend solutions and future actions. This study could serve as a framework for other fruit and vegetable value chains that cross borders in order to achieve the intertwined objectives of reducing food loss and assuring food safety in support to developing sustainable and inclusive food systems in the Greater Mekong Subregion (GMS) that comprises less developed (Cambodia, Laos, Myanmar, Vietnam) and developed (Thailand and China) economies.

METHODOLOGY

This research combined secondary and primary data collection and analysis. Secondary information was obtained through documentary studies of previous value chain studies sourced from publicly available literatures, research reports from government agencies and external development partners, and FAOSTAT statistical data. Relevant studies and data are included and referenced in this study, and alternative analysis was carried out. Primary data collection was performed through onsite surveys to validate and substantiate the secondary information and gather first-hand data that were not gathered in previous value chain studies. The surveys focused on smallholder mango farmers who were either Cambodia Good Agricultural Practice (CamGAP) compliant or non-compliant. Five focus group discussions (FGD) for non-CamGAP farmers in Kampong Speu and CamGAP farmers in Kampong Cham, and 5 key informant interviews (KII) of market intermediaries (collectors/exporters) were conducted in August 2023 to collect quantitative and qualitative information on the following:

1. Value chain stages and practices
2. Postharvest practices of CamGAP-compliant and non-compliant farmers with emphasis on food loss and food safety problems
3. Reasons for adopting CamGAP and the needs of smallholders in order to sustain it
4. Reasons behind contracting mango trees to collectors or importers and farmers' needs to enable them to engage entirely from production to marketing
5. Practices of CamGAP-compliant farmers to reduce food loss (Product Quality Module) and assure food safety (Food Safety Module) as well as those of non-CamGAP farmers
6. Magnitude and causes of food losses
7. Food safety problems for which they have been implicated
8. Knowledge of the interconnection/nexus of food safety and food loss reduction and the practices and benefits
9. Adequacy/inadequacy of support systems.

Descriptive analysis of results is presented here and starts with a brief profile of mango production. A value chain map is then presented, substantiating previous reports of Meng (2021) and CPSA (2020). Value chain practices and problems are synthesized, and at each

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value chain stage, food safety and food loss implications are indicated. Finally, future actions addressing key constraints and problems are recommended.

RESULTS AND DISCUSSION

Production Overview

Global mango production in 2021 amounted to 58.3 million tons and is set to reach 65 million tons by 2026 (Mango Market Outlook 2022-2026). India is the world's largest mango producer, providing 27.2 million tons. Indonesia, China, and Mexico are the next three leading producers, respectively. Aside from China, Thailand is the other GMS country that ranks in the world's top 10 mango producers. While mango production is large, only a small proportion (less than 4%) enters the international market indicating high domestic demand for mangoes. The top mango exporters are Mexico, Brazil, Peru, and Thailand while the top importers are the United States and European Union (FAO, 2023). Global exports of mango, which constitutes 83% of the FAOSTAT data on mango, mangosteen and guava, amounted to approximately 2.1 million tons in 2022. Imports by China, the third leading global importer in 2021, increased by 16% in 2022, to approximately 350,000 tons, equivalent to an estimated 16% of global imports. China requires official phytosanitary certificate, certificate of origin, and permit to import quarantine material, while countries like the United States, Japan and Korea have stricter requirements (ITC, 2019). China has made substantially higher imports of mangoes from Vietnam and Cambodia, which respectively reached 50,000 tons and 28,000 tons. Cambodia exports mango to Vietnam which re-exports them to China.

Mango is grown in all 25 provinces of Cambodia, with Kampong Speu having about 60% of the total production area of 65,250 ha (Figure 1). Total production volume was 1,274,730 tons

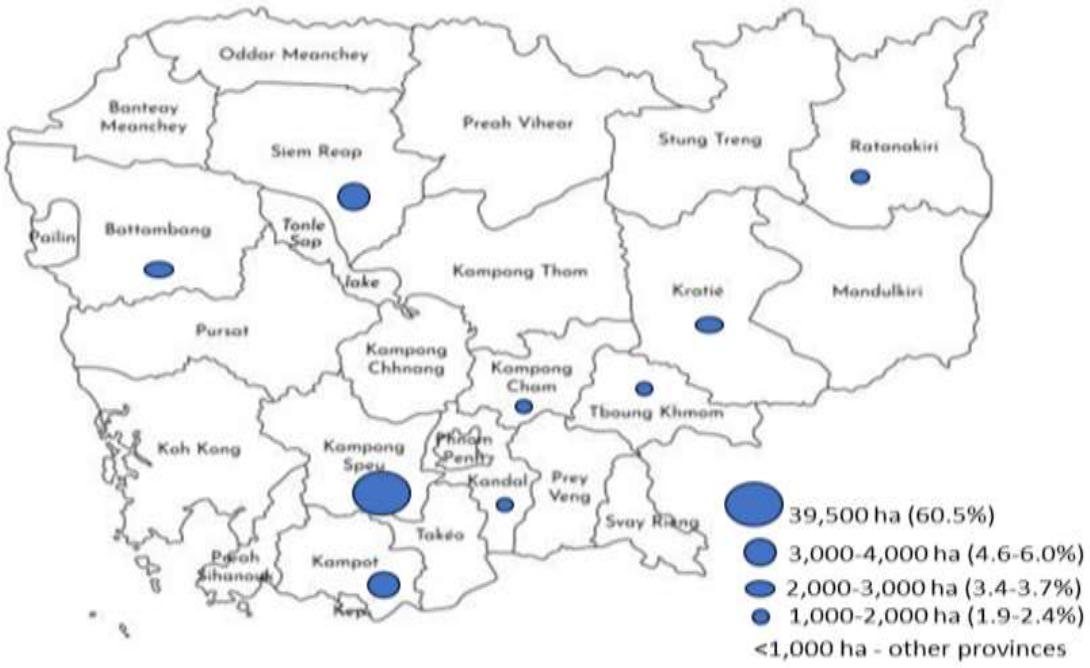

Figure 1: Mango Production Areas in Cambodia Provinces (Department of Horticulture, GDA, MAFF, 2018)

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in 2018, 62% of which is contributed by production in Kampong Speu. Far second largest mango-producing provinces are Siem Reap and Kampot (3,000-4,000 ha), followed by Battambang and Kratie (2,000-3,000 ha), and Kampong Cham, Kandal, Tboung Khmom and Ratanakiri (1,000-2,000 ha). The other provinces have less than 1,000 ha. FAOSTAT (2021) data revealed quite different 2018 figures of total mango production area (100,092 ha) and volume (1,042,469 tons) (Figure 2). It also showed increases in production area of more than 37,000 ha and production volume of more than 400,000 tons in 2020 over that in 2018. This discrepancy may be due to the nature of FAOSTAT data which lumped the values for mango, mangosteen and guava.

The increase in mango production was tremendous, from 5,048 ha and 67,319 tons of fruits in 2016 to 137,950 ha and 1,495,989 tons of fruits in 2020. Similarly, export increased sharply from 332 tons in 2016 to 97,628 tons in 2020 (Figure 3) (GDA, 2021; ITC, 2021). Export markets include Vietnam (39.4%), Philippines (34.9%), Korea (9.1%), Singapore (6.1%), and Thailand (3.5%); European countries that imported the most are United Kingdom (1.9% of total exports) and France (1.7%). However, unrecorded informal trade across borders to neighboring countries may involve much bigger volume of mangoes, estimated at over 945,000 tons fresh mangoes in 2020 (Phal, 2020).

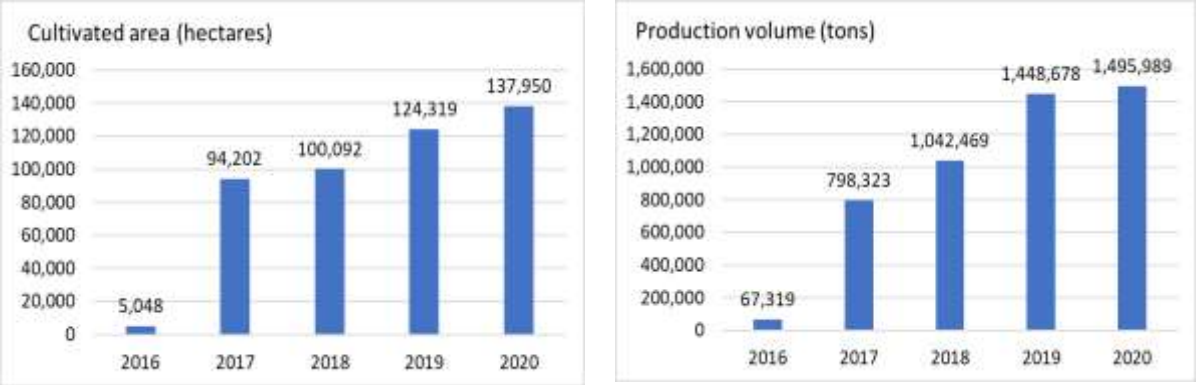

Figure 2: Mango Production Area and Volume in Cambodia from 2016-2020 (FAOSTAT, 2021).

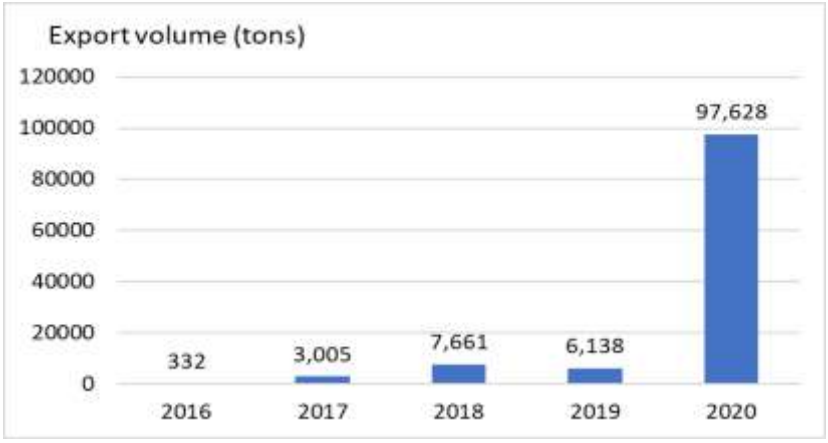

Figure 3: Cambodia Mango Exports, 2016-2020 (GDA, 2021; ITD, 2021).

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Crossborder Value Chain

Figure 4 shows the crossborder value chain map of Keo Romeat mango. It deviated from that reported by Meng (2021) and CPSA (2020) which included domestic chain in addition to export chain.

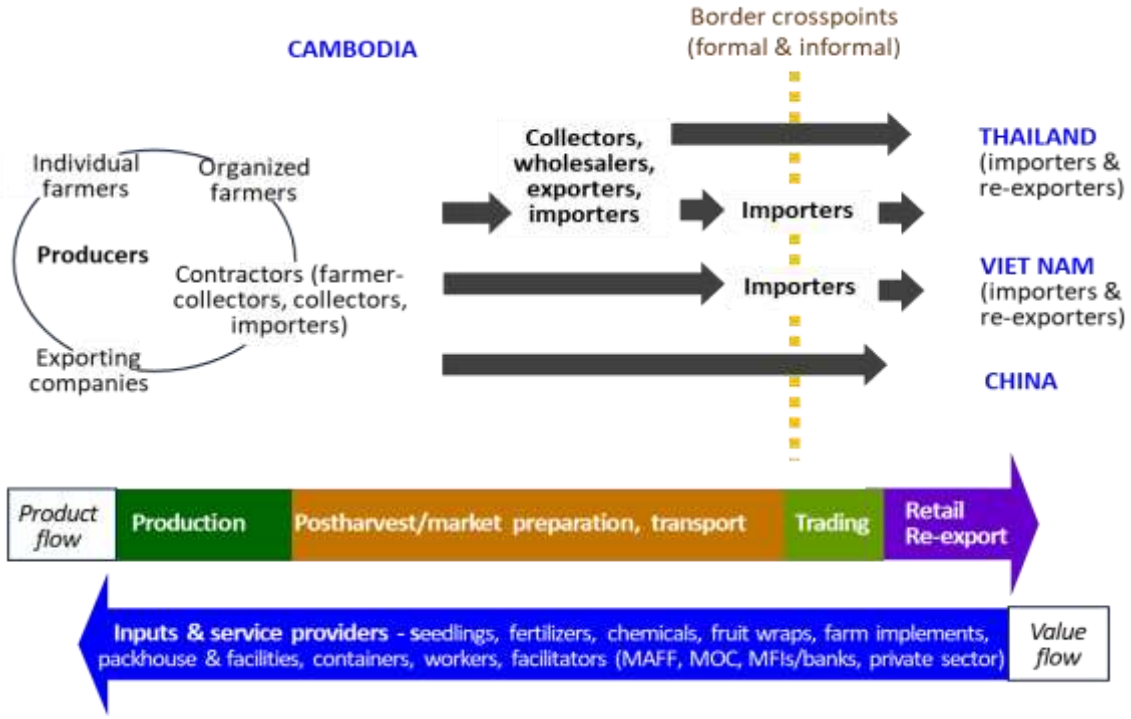

Figure 4: Crossborder Value Chain Map for Cambodia's Keo Romeat Mango

Salient points of the value chain, which were not captured in earlier value chain mappings, are as follows:

1. Input supply, including postharvest inputs, and service providers or facilitators/enablers are a vital part of and provide value for the chain.
2. As producers, contractors (farmer-collectors, collectors and importers, all of whom are traders) can bring mangoes to the border or to final destination in importing country like Vietnam and Thailand.
3. Foreign-controlled export companies produce or source local mangoes for export. Similar set up exists in other exporting companies, such as Hyundai Mao Legacy Co Ltd which grows mango on 2,400 ha of land and operates a mango processing plant, both in Kampong Speu province's Phnom Sruoch District, to export fresh Keo Romeat mangoes to South Korea.
4. Local Cambodian companies contracted to supply Keo Romeat mangoes to importing companies in neighboring countries. One case is the Angkor Green Investment Development which supplies Keo Romeat mangoes to Thailand-based Japanese companies that export frozen mangoes to Japan. Similar set-up operates for local suppliers of mangoes (local companies, collectors/traders and Thai traders) to supply Thailand-based Chinese companies that export mangoes to China.

5. Mango farmers are either individual operators or operate as a group or cooperative. Individual farmer-operators are easy prey of manipulative market intermediaries and because of lack of scale, resources, capacity and options to take risks, the only easy and risk-free option for them is to lease the mango trees to contractors at a time (flowering or fruiting stage) when more economic gains are within reach. These limitations are minimized when farmers operate collectively as a cooperative which also serves as a support system (from input supply to marketing) and entry point for development interventions focused on smallholders.

Crossborder trade of Keo Romeat mango starts as early as at the input supply sourcing up to final stage of reaching the crossborder market destinations in GMS – Vietnam, Thailand and China. However, most of the crossborder transactions happen before mangoes are harvested by Vietnamese contractors and at the borders with Vietnam and Thailand. In addition, foreign companies operate inside or outside Cambodia that source Cambodian mangoes and undertake pre-export and export operations, such as Chinese companies in Cambodia and Thailand exporting fresh or processed Cambodian mangoes to China, and Thailand-based Japanese companies exporting mangoes to Japan. These arrangements could be studied to come up with policies and actions that will better benefit Cambodian players in crossborder chains.

Input Supply

The value chain begins with input suppliers including nurseries supplying grafted mango seedlings. On average, nurseries produce 16,500 grafted seedlings annually. Nursey owners sourced mango seeds from their own stock and from other producers. Other inputs include fertilizers, insecticides, herbicides, fungicide, fruit wrapping materials, chemical flower inducer, farm implement and fuel. Fertilizers are used by 87% of farmers; insecticides by 84% of farmers; herbicides by 70% of farmers; and fungicides by 25% of famers. Farmers procure these inputs from shops near their residence and when unavailable, they source them from provincial towns or Phnom Penh. People living near Thai and Vietnamese borders also buy inputs from Vietnamese or Thai shops. Input suppliers accept payment in cash or credit. Equally essential are postharvest inputs that include plastic crates as packaging containers, clippers for fruit stem trimming, handling aids, and packing area. Some importers provide plastic crates to farmers and collectors.

Production

Farmers and contractors are the producers of mango. About 80% of producers are smallholders with less than 5 ha of mango orchard, while 13% and 7% have 5-10 ha and more than 10 ha of land, respectively. About 97% of farmers grow without a contract; the 3% with contract were in Kampong Speu. Centralized contracts are used where buyers purchase from a large number of producers at an agreed upon price based on fruit quality.

Farmers are responsible for establishing and managing mango trees. They operate individually or collectively as a cooperative or association. Some farmers do not take risks; they lease their mango trees to contractors who are either farmer-collectors, collectors, importers from Viet Nam or Thailand, or exporting companies. Reasons for leasing the mango trees to contractors include lack of capital for necessary inputs, lack of technical knowhow in tree management particularly at flowering and fruiting stage, lack of labor particularly during harvesting, and lack of market connection. The contractors control all production and harvesting operations. Contractors pay farmers based on the number and age of trees; 2021 data are USD 3/tree for 3- to 4-year-old (yo) trees when a full harvest is expected, USD 9/tree for 6-8 yo trees, and USD

18-20/tree for 10-15 yo trees. This is a low-return arrangement for farmers considering that each mango tree can yield 100-300 kg fruits and if the price is USD 0.3/kg particularly during the off-season, gross return is about USD 300/tree. Therefore, farmers should be supported to engage in the entire production cycle including marketing. On average, one contractor can manage 5,000-6,000 trees (200-300 trees/ha) in addition to their own mango orchard, and most contractors focus on off-season contracts for higher profits.

A feature of the Cambodian mango industry is the widespread practice of producing 2-3 crops per year. Main season is from April to May while the first and second off-season production is from September to November and from January to March, respectively. To achieve this, chemicals are used to induce off-season flowering, in particular paclobutrazol and thiourea. Paclobutrazol has negative impact on tree health while thiourea is a potential carcinogen (NTP, 2021). Alternative safer treatments developed include mono-potassium phosphate and potassium nitrate (Hickey, 2019). Potassium nitrate is the common mango flower inducer in other countries like the Philippines. Furthermore, mango has a biennial bearing (alternate bearing) habit, producing fruits heavily on one year followed by no or less fruit yield the following year. Heavy bearing depletes the energy reserves of the tree and jeopardizes flower and fruit formation of the coming year hence the reduced yield. This is not the case for Keo Romeat mango as it can flower and bear fruits 2-3 times a year by employing flower induction for off-season production. The practice has to be examined as it can severely stress the trees that could lead to future unproductivity or death of the trees. However, biennial bearing can be reduced by various means, including pruning, fertilization, controlled irrigation and use of vigorous cultivars.

Mango production basically employs chemical agriculture as can be seen from the chemical inputs used and frequency of application based on the schedule for off-season mango (Som, 2019):

April-May:	application of inorganic fertilizer combining complete fertilizers (15-15-15 and 25-15-15), incomplete fertilizer (18-46-0) and single fertilizer (urea = 46-0-0)
June:	Thiourea, 2 times or once a week
July:	application of potassium nitrate (KNO_3) as flower inducer, 3 times/week
August:	application of Atonex fertilizer and Dithane fungicide, 12 times
At fruit set:	application of fungicides Cabendazin and Dithane
October:	harvesting

Non-CamGAP farmers and farmer-collectors in Kampong Speu do not practice fruit bagging but spray insecticide and fungicide everyday if rainy and if there is no rain, spraying depends on visual observation of the presence of pests. Spraying starts once the inflorescence develops and ends 2-3 days before harvest. There are also farmers who do not spray pesticides but practiced fruit bagging.

Some farms/farmers, particularly the organized ones, are certified compliant to Cambodia Good Agricultural Practice (CamGAP) as a food safety management system. Major motivations to adopt CamGAP among organized 60 farmers of Angkor Green Investment Development from Kampong Cham, Kampong Thom, Pailin and Siem Reap include premium price of fruits which is 40% higher than non-CamGAP fruits; easy access to production inputs; and sure market (Thailand-based Japanese Company exporting frozen mango to Japan). GAP

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has also been introduced to smallholder mango farmers through various training and technical assistance programs of government and development agencies. For example, the USAID-funded Harvest II Program provided CamGAP training to 140 mango farmers and following the training, 67 farmers applied for and received CamGAP certification (Abt Associates, 2022). CamGAP farmers follow a crop program or production schedule in order to have mango harvest every month from November to April. Fruit wrapping is not practiced presumably because the fruits are destined for processing to extract the ripe pulp and quickly freeze it before export. CamGAP is patterned after the ASEAN GAP, which has 4 modules (Produce Quality, Food Safety, Environmental Management, and Worker Health, Safety and Welfare). The Produce Quality and Food Safety modules mainstream both food safety and food loss management.

Fruits are harvested mature green using picking poles. Frui yield averaged at 13.5 tons/ha, the highest in ASEAN (Figure 5) (FAOSTAT, 2021). This indicates an advantage of mango production in Cambodia over other countries especially Indonesia, Thailand, and the Philippines which are major mango producers in ASEAN.

Cambodian farmers have comparative advantage as they can produce mangoes cheaper than importing them as implied from the fact that Thailand, Vietnam and the Philippines imported Cambodian mango to supply their processing factories. However, these advantages of Cambodian mangoes could be transitory, the future may not be as bright as today if unsustainable production and marketing practices continue. To avert this and to make the future brighter, experiences of other countries which have engaged in mango production and export for decades could be used as reference. It is worth deciphering why the Philippines, a major mango producer and exporter in ASEAN, has the lowest productivity and is importing mangoes from Cambodia, in fact the second largest importer of Cambodian mangoes.

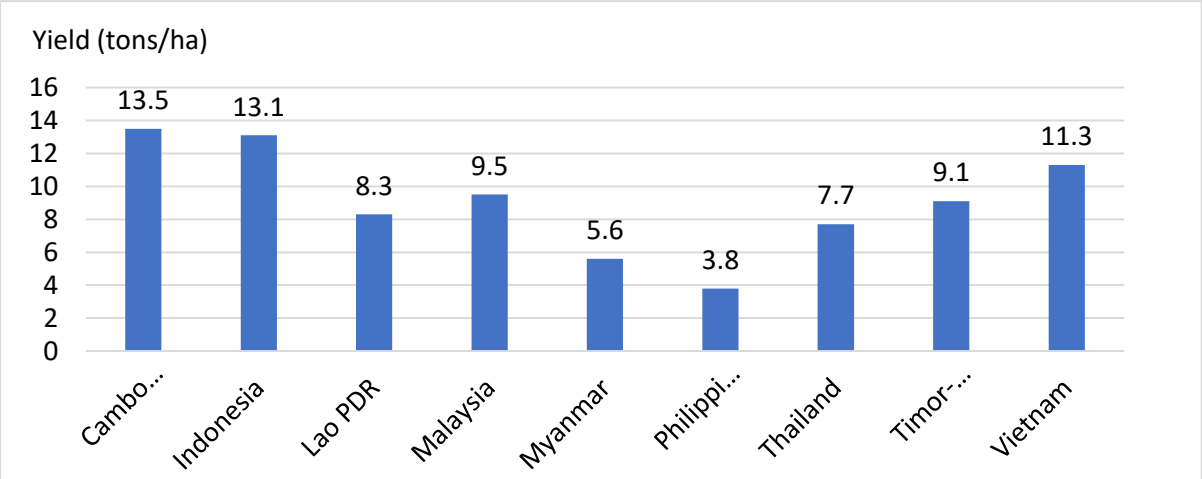

Figure 5: Average Yield (tons/ha) of Mango in ASEAN Countries (FAOSTAT, 2021).

There are deficiencies during harvesting which are potential causes of food safety and food loss problems, such as leaving the harvested fruits on bare ground which is a rich source of spoilage and human pathogens; dumping the harvested fruit during field consolidation which can result in visible and invisible bruises, the latter becoming visible when the fruit ripens as green or brown spots; mixing harvested fruits in bamboo baskets which cannot offer adequate protection against physical injuries and also could result in latex staining. Physical injuries predispose the fruits to microbial decay and human pathogen contamination.

During on-season when fruits are abundant, only big-sized fruits are harvested apparently because mango grades are based on size or weight. Small-sized fruits are left on the tree which later fall to the ground providing breeding ground for insect pests and diseases.

Food safety and food loss implications during production – Chemical agriculture is unsustainable. Farmers frequently use excessive amounts of chemicals on mango trees which may have negative effects on food safety and workers' health. This problem could be minimized with the adoption of CamGAP but at present, only few farmers are adopting CamGAP. On the other hand, food loss is serious. In conventional farms, fruit losses range from 25-30% while in CamGAP farms, 10-15% due to insect damage, adverse weather, small size and fruit fall. Solutions to these losses are needed and may include fruit bagging which is not widely practiced, fruit thinning and/or mineral nutrition interventions to promote fruit development and inhibit fruit abscission, and production scheduling in order to avoid adverse weather conditions. Furthermore, losses can also be caused by climate change and poor farm management. Too much rain and long droughts during flowering have negative effects on mango fruit setting, depressing fruit yield and quality. Heavy rain followed by a prolonged drought in 2019 decreased mango yield by nearly 50%. A range of factors affect fruit quality and quantity. If fruit-protection covers were not used, some 5% of fruit suffered defects from pests and 50% of fruit have dark skin which can decrease fruit color quality. Harvesting too early decreases sweetness of ripe fruit and harvesting too late decreases fruit shelf life.

Postharvest

Some farmers and contractors sort, grade, pack and transport mangoes after harvest. The sorted fruits are then classified into two grades: Grade 1 - 3 fruits/kg, well colored and no disease and insect damage, and Grade 2 - 4 fruits/kg with small defects. Small-sized fruits are included under Grade 2 in the off-season, and are thrown away in the on-season. Prior to sorting and grading, fruit stems are trimmed and the fruits are placed upside down on a latex drainer. Some farmers, particularly those exporting to Thailand, wash the mangoes, followed by airdrying before packing. Other postharvest techniques have not been employed yet, such as hot water treatment for postharvest disease control and vapor heat treatment for fruit fly control which is a quarantine treatment to enable entry into higher value markets like Japan and South Korea. Also, food safety enhancing treatments, such as sanitizing treatment, are not employed.

Mangoes for export are packed in plastic crates with paper liner (Figure 6) which is a good practice if the crates are reused – this has lower carbon footprint than the one-time use of carton boxes as practiced by other exporting companies (Lopez-Galvez et al., 2021). In some cases, the crates are provided by the importers. There are two sizes of plastic crates being used – 25 kg and 40 kg capacity (Figure 8). Mangoes are packed to give a gross weight of 28 kg (for 25 kg capacity crates) or 43 kg for 40 kg capacity crates but only 25 kg or 40 kg will be paid by importers. Taking out the weight of the plastic crate of about 1 kg, there is 2 kg fruit free of charge as allowance for loss, which

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Figure 6: Plastic Crates with 25 kg or 40 kg Capacity and Truck Transport of Mangoes

is equivalent to 5-8% outright volume loss on the part of the producers/suppliers. This is true only with conventional farmers while it is not an issue with CamGAP farmers.

Truck transport is usually employed to bring the crates of mangoes (16-18 tons/truck) to the border where most transactions take place (Figure 6). Storage is not practiced because the operations are done quickly; for example, if harvesting is done at 2 pm, the fruits are delivered at 8 pm on same day. Transport is usually done at nighttime to avoid the heat during the day

Food safety and food loss implications during postharvest: Mango growers face tremendous challenges because of poor postharvest quality due to deficiencies in postharvest handling, lack of cold storage and cold chain, lack of systematic packing facilities, and non-adoption of internationally-recognized production and processing standards, such as GMP and HACCP. Overall, postharvest food loss amounted to 25-28% for conventional producers and 10% for CamGAP producers. Faulty practices that could lead to food safety problems are evident, such as including leaving fruits on bare ground, lack of sanitation during fruit preparation and packing, and lack of food safety-enhancing technologies such as decontamination or sanitizing treatment and hot water treatment.

Marketing

Producers have two choices to market mangoes – direct sale to international traders who are mostly Vietnamese, or sale to collectors who are small, medium, and large in size of operation, or wholesalers. Small and medium collectors sell mangoes to large collectors who in turn sell mangoes to Thai and Vietnamese traders at the border. Most exports of fresh mangoes go to Viet Nam and Thailand where they are purchased by processing companies. Based on USAID's recent Agriculture Competitiveness Opportunity Assessment, there is generally little coordination and aggregation among farmers (USAID, 2019).

Contractors' costs and profit are dependent on lease per tree, input and labor costs and the price of mangoes. If the lease fee is USD15/tree and one hectare has 260 trees, contractors will pay USD3,900/ha plus input and labor costs of about USD1,000/ha. Therefore, with an average yield of 15.4 ton/ha, contractors need to receive a farmgate price of at least USD0.31/kg as the threshold to break even. Cambodian value chain actors receive lower profit (about UDS12/ton) than Vietnamese wholesalers (USD50/ton) and traders (USD20/ton). Thus, most of the value received for Cambodian mangoes accrues to importers which can be reversed with support and capacity building for the former.

Some large collectors/traders are also registered exporters, and they export mangoes to Thailand, Vietnam, China, the Philippines, Singapore, Korea, and some European countries. Although there is no clear data about the volume of exports to each country, it is expected that the neighboring countries of Viet nam and Thailand import most of the mangoes because about 90% of total exports (about 57% of total production) is done unofficially. Only about 6% of production is officially recorded as export.

Mangoes sold to collectors or large traders for export have lower price for on-season fruits than off-season fruits. The average farmgate price during on-season is USD0.33-0.43/kg for grade 1, USD0.20/kg for grade 2, and USD0.18-0.50/kg for ungraded. In comparison, the average farmgate price during the off-season was USD0.38-0.55/kg, 0.20-0.33/kg, and 0.35-0.58/kg for grade 1, grade 2, and ungraded fruits, respectively. However, price fluctuates greatly. For example, mango price in February 2021 plunged to USD0.17/kg and was only USD0.04/kg for unpacked mangoes. The situation in 2020-2021 was abnormal due to the COVID-19 pandemic.

Wholesalers come from Phnom Penh Damkor and Neak Meas markets, sourcing mangoes from all provinces and selling them to retailers in the city and other provinces. This channel accounted for about 37% of total production in 2020. Wholesalers also export mangoes to other countries. During the off-season from September to December, they exported 50 tons/day to Thailand, 20 tons/day to Vietnam, and 18 tons/day to China. Export mangoes have different prices: in 2015, price for grade 1 fruits was USD0.40-0.50/kg to Thailand, USD0.50/kg to Vietnam, and USD0.70-0.75/kg to PRC.

Market information is mainly sourced from Thai and Vietnamese traders. These traders collect all information from importing countries; price and quantity demanded are then set, and the information is shared with the main collectors who source mangoes for them. Collectors are the main source of information for producers. However, collectors usually do not share all information because they want to get more profits from producers. Producers were concerned about the price of mangoes, most collectors know that the price of mangoes will increase with increasing opportunities to access new export markets, but this information is not shared with producers. Because mangoes cannot keep for a long time on the trees, growers need to harvest them when they are ready. As Cambodia depends mostly on neighboring countries for selling mangoes and there are no large processing factories in the country, farmers have no choice but to sell their mangoes when they are really cheap.

There are three emerging Market Information Systems (MIS) under MAFF, Ministry of Commerce (MOC) and the Tonlesap Project. The state-owned MIS is under two ministries: MAFF and MOC, while Tonlesap is an online, private sector initiative. MAFF focuses on agriculture commodities at the wholesale and retail levels, while MOC focuses on multiple commodities such as agriculture, furniture and import and export of goods. Tonlesap provides an agriculture commodities application.

Keo Romeat mangoes can be supplied to markets for about nine months as it can be produced both on-season and off-season. But off-season production is not enough to supply market demand and there is no fruit supply between June and August. The producer price index of mangoes shows that the annual average price is increasing over time from 99.18 in 2015 to 106.92 in 2018. Better returns during off-season production are expected because mango price is higher by USD0.20-0.25/kg than that of on-season fruits. Market arrangement between growers and traders is good in the informal trade of mangoes to Vietnam buyers. Traders negotiate a price with farmers before harvesting seasons and take care of all activities during harvest (Goletti & Sin, 2016). To expand mango exports, Cambodia negotiated with China and received a 500,000 tons quota to export mango to China. On 9 June 2020, specific requirements of phytosanitary for mango export were officially signed by both countries (Emily, 2021). Additionally, Cambodia and China signed a Free Trade Agreement on 5 October 2020 (GIZ, 2020). This will give good opportunities for Cambodian agricultural products to access China markets. From these agreements, Cambodia hopes to increase the export of fresh mango to China in the future.

Enabling Environment

Enabling policy is existing. Mango is a priority in MAFF's Crop Master Plan 2030, with a vision that Cambodia become one of the five major exporters of quality fresh mango in the world. According to the master plan the Cambodian government is prepared to spend $18.4 million over the next 15 years bolstering the mango supply chain.

Service providers facilitate the mango value chain. At the national level, MAFF is responsible for regulations, strategic plans, and policies to support agriculture development. At the provincial level, MAFF's staff work closely with producers by providing technical training, extension services, and other activities to support agricultural communities. Currently, there is no specific policy for mango development in Cambodia but ASDP 2018-2023 highlighted activities focused on mango ranging from production and processing to marketing and trade. MAFF has successfully reached an agreement on SPS requirements with China for exporting fresh mangoes. However, most growers learned techniques of flower manipulation for off-season mangoes from traders, not from agricultural experts. This shows the limitation of the implementation of the agricultural extension policy since 2015 which focuses on improving farmer's knowledge, skill, and technology to improve mango production.

MOC is responsible for facilitating trade-related activities and finding new markets for exports. Banks and microfinance institutes (MFIs) provide financial services in terms of loans to value chain actors while input suppliers provide technical advice to farmers.

Non-government organizations (NGOs) and foreign capital investments play a vital role in Cambodia's agriculture value chains, providing technical assistance, research, and capital investment. GIZ and JICA identified Asian markets as important opportunities, but identified technical assistance and market information as areas where producers need support. USAID's HARVEST II program is working with processors and suppliers to help develop joint growth plans and is generally offering business development services to the sector. It is also doing some technical assistance for producers and providing private sector-oriented grants to catalyze innovation. It has noted that there is a lack of technical skills for suppliers, for example on packaging, grading, processing, and there was a need for more working capital.

Challenges and Opportunities

The greatest challenges are lack of capital funding, production, postharvest and processing capacities, and access to market. Opportunities include the untapped potential of export value chain, private sector processing, and expanding production.

Capital Funding

Actors in the mango value chain can access capital/credit through the bank and microfinance institutions (MFI). More than 30 MFIs are providing loans in Cambodia and many of them are lending to communities; however, their interest rates are very high. A farmer might engage more than one MFI at a time and they have difficulty in paying the loan. They mostly rely on the remittance from their family's migrant worker. The banking sector grew significantly from 2011. The interest rates of both banks and MFIs are relatively high for the agriculture sector. The average annual bank interest rates were around 16% on loans and 5% on deposits; however, the interest rates charged on loans by MFIs were 27.4%. There should be a mechanism to lower the interest rates, as other countries in the region have. A recent regulation of the National Bank of Cambodia requires interest rates to be no higher than 18%.

Production Practices

Harvest of mango occurs between April and May and there can be up to three harvests. Over the last 10 years, Keo Romeat has become the most popular variety both for local use and export. This variety is able to provide two additional crops per year in the off-season from September to February as mentioned earlier. Keo Romeat is famous in Cambodia and Thailand and the growers have not shown interest to grow other varieties. The Cambodian Agriculture Research and Development Institute (CARDI) conducted research to develop other mango varieties. Two varieties were released in 2006 (Keo Reach and Keo Tep). Both varieties performed well and had nice ripe fruit characteristics, but have not been adopted by the industry. There are some common production practices used regionally that could provide higher yields in Cambodia. For instance, in Thailand, trees are pruned to control size, enhance yield, and decrease pests and diseases, and fruits are thinned 35-40 days after fruit set retaining the best growing fruit. Inducing off-season flowering to force mango trees into producing fruits twice a year rather than once is common practice in Thailand, and is becoming so in Cambodia.

A growth-inhibiting hormone, Paclobutrazol, is applied to the soil and taken up by the mango tree roots to induce flowering in the off-season. Knowledge around soil type is important for paclobutrazol application, as residues can remain in the soil - particularly in clay soil where drainage is poor. This is an area of training and extension that should be focused on in Cambodia as paclobutrazol becomes more widely used. Water management is also very important - for quality mango development irrigation is essential, especially from flowering to fruit development stages. Yet, in Cambodia, only around 7% of farmland is irrigated. While there is some donor support to build new irrigation infrastructure, coordination among different ministries remains low. This is another area of intervention that should be focused on to improve mango production in Cambodia. Mulching can also be employed to keep moisture in the soil and suppress weeds. Because expanding mango growing operations is time and resource intensive, farmers can look to diversifying their growing systems. Since mangos are usually planted wide apart and have a juvenile period of 4-5 years, spaces in between trees can be utilized for growing other crops that farmers can profit from. Wheat can be sown if separate irrigation is provided to the mango plant, and pulses are a great option that fix nitrogen, which can be used by mango trees, Vegetables can also be grown in between rows as an additional

source of income. Therefore, diversifying production systems may be another area that extension in Cambodia should focus on.

Postharvest Capacity

Harvesting and handling of fruit after harvest is critical, as it will dictate flavor and shelf life. The more mature a mango when harvested, the better the flavor when ripe. Proper harvest maturity and methods to determine it are important area of focus in farmers' training. Careful postharvest handling is also essential, as mechanical injuries hasten deterioration and ripening, and provide infection sites for microorganisms that can cause decay. Due to the nature of seasonal mango harvest and temporary harvest personnel in larger mango operations, there should be a special focus on retraining harvest crews. Harvest crews must take care to avoid latex dripping from mango stems onto the fruit skin once they are cut causing latex stain or latex burn which degrades the appearance quality of the fruit. Special equipment has been developed in Thailand to handle small- to medium-sized production loads. As seen in Figure 5, mangoes are held upside down on mesh as latex drainer after fruit stem trimming, so the latex can drip out. Different layers of mango can be added, with tarps in between to catch the latex as it drips between the layers. In addition, mangoes should not be exposed to the heat of the sun after harvest. Sun exposure increases fruit temperature and metabolic activities which shorten shelf life. Mangoes undergo rapid changes in as little as 24 hours after harvest, including changes in total soluble solids (TSS) content, flesh firmness, and skin and flesh color. Avoiding high temperatures reduces the rate of physiological and biochemical changes, minimizes water loss, and slows the growth of microorganisms that might cause decay. For these reasons, lack of shade structures and cold storage facilities in Cambodia should be addressed in order to increase mango quality for export.

Processing Capacity

Processors constitute about one-third of agri-businesses; however, processing is focused on rice, with very little activity in most other value chains. In general, Cambodia is less competitive in processing due to challenges of poor energy infrastructure, high energy costs, and lack of skilled labor to operate processing factories. Electricity costs in Cambodia (USD 0.17/kWh) are much higher than those in Vietnam (USD0.11/kWh) and Thailand (USD0.13/kWh). Cambodia also has more limited access to the electrical grid than regional actors, and sourcing electricity for a large processing facility in Cambodia costs upwards of $25,000. Nevertheless, value-added products remain a potential market opportunity. Mango products have risen in popularity in the past 10 years. Frozen, canned, and dried products are being produced in Thailand and appropriately-scaled processing facilities could be designed for Cambodia. Investment in this area could increase profitability and diversify income.

Export of Fresh Mango

Exporters of fresh mango fruit face additional challenges, such as policies that require exporters to submit certificate of origin with paperwork requiring 10 business days before exporting, which is difficult when handling perishable products. There is also a largely inoperative SPS system. This has contributed to the informality of crossborder trade which could be addressed through appropriate market facilitation and incentive measures.

Recommendations

In addition to the recommendations included in the foregoing challenges, the following interventions could be pursued to mainstream food safety and food loss reduction and improve

crossborder mango value chain efficiency and sustainability. These actions should align with national strategies to widen adoption of FSMS that include CamGAP as singled out in the master plan for crop production 2030 (Goletti & Sin, 2016) and trade integration strategy (RGC, 2019a), and GMP and HACCP as part of the strategic programs of the agro-industrial development strategy 2019-2030 (RGC, 2019b).

a. Build capacity to provide consistent quantity and quality of mangoes for international markets through better producer knowledge of production and postharvest best practices:

- Develop training of trainers programs in partnership with the MAFF Department of Horticulture. Extension agents need to be trained on best practices in the field and after harvest to provide advice to producers and aggregators of mango. Farmers need to understand why processors are requesting specific practices and why these practices are important to increase their adoption and compliance.
- Increase extension to farmers on best production and postharvest practices. Mango orchards require intensive farming practices to establish and long-term strategies to manage tree health over an orchard's lifetime. Mangoes are also a delicate crop that necessitates the use of best practices at harvest and throughout the value chain. Growers need to understand the requirements of different market outlets, including exporters, processors and local markets. Direct training programs should be implemented to provide farmers and aggregator's information on mango varieties, tree irrigation and fertilization, pest management practices, phytosanitary requirements, best harvest maturity for each market outlet, harvest procedures to select the right maturity and avoid fruit injury, and postharvest techniques.
- Identify contract farmers to participate in extension activities. To meet export goals, new contract farmers and land needs to be identified. This should be led by a private company that has significant capital to match any donor activity.
- Develop producer associations for smallholder farms. This strategy works consistently around the world to disseminate information quickly among farmers and also give producers the ability to aggregate their product for larger markets and negotiate input prices. This should be combined with a direct training program as recommended. Ideally, this work should leverage other NGO farmer-based organization work. The alternative is that the farms receive inputs and capacity building from the exporter; however there does not appear to be good trust between the producers and the exporters at this time. It is possible this relationship could be strengthened through direct intervention/assistance.

b. Ensure product quantity and quality in value chain through better market linkages and postharvest facilities

- Hold meetings of relevant actors to identify available Cambodian infrastructure necessary for export. MAFF should coordinate the meetings with the private sector to understand the landscape of current enterprises and potentially connect smallholders with larger enterprises with more sophisticated equipment. Majority of mangoes are grown by smallholder farmers. This decentralized system of growing causes significant barriers to aggregating mangoes within and across regions. Further, value chain actors such as traders and exporters are not sufficiently linked to producers to provide a

consistent pipeline of mangoes. Government officials are not aware of private sector infrastructure or how to implement cost effective SPS equipment.

- Develop joint ventured postharvest centers with capacity for sorting, grading, de-stemming, washing, packaging, storage and other essential operations. These centers would be an aggregation point for fruits destined for large export markets. A joint venture between a leading exporter, MAFF, and NGO would be ideal.
- Develop a market information system on supply and demand, prices at aggregation points, pick-up days, harvest/grading tips and other relevant information.

c. **Ensure long-term sustainability of Cambodian mango export through understanding market demand and shipping capability of the Keo Romeat variety**

- Organize country visits to understand market demand for Keo Romeat mango. While Thailand noted how valuable the Keo Romeat variety is in its green form, other markets may not be as interested in a green mango variety. The Keo Romeat is flavorful when ripened to full maturity, however the taste compared to other varieties in the market is not known. Partnering with export market firms to understand cultural preferences would be ideal.
- Understand shipping behavior of Keo Romeat mango for green consumption and ripe consumption. Depending on the tastes and distance of a market, the Keo Romeat should be harvested and shipped at different stages of maturity. These nuances can make a big difference when establishing large national value chains.

Declaration of Competing Interest

The authors declare no conflict of interest.

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