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Original Research Article

Quantity and quality assessment of food loss on the farm for the tomato production system; a case study in Hot District large-scale farming group, Chiang Mai, Thailand

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ABSTRACT

The objectives of this research were 1) to identify causes of loss in tomato production, and 2) to assess the loss of quantity and quality of tomatoes at the farm level. Little is known about tomato losses among small-scale farmers of Hot large-scaled farming group of Chiang Mai in Thailand. A semi-structured questionnaire was used to collect data on the causes of tomato losses, quantity, and quality of tomatoes lost on the farm during the harvesting period. In-depth interviews through focus group discussions were done to gain a deeper understanding of tomato food loss. According to the results, the main cause of food loss in this farming group was weather variability 63.3% of farmers never use any climatic measuring tools, for instance, hygrometer, temperature, and rain gauge to guide farm operations. The mass of tomato loss was approximately 11.63% or 728.09 kilogram/rai translating to an economic loss of 12,377.60 Bath/rai. We also find nutrient losses in form of energy, carbohydrate, phosphorus, potassium, and vitamin C worthy 1,377,081 kcal/rai, 207,188 g./rai, 1,439.676 g./rai, 11,767.784 g./rai and 1,439.676 g./rai respectively. This shows quantitative and qualitative loss of tomatoes which may affect the economic and nutritional value as well as food safety and food security. Although many farmers realize the food loss problems, they cannot determine how much loss occurs in production procedures. In this regard, the result of this research can be applied to stimulating the farmers' awareness of losses in the production system and designing a training program for farmers to prevent and reduce losses. However, a key challenge for recovery efforts is the variability and unpredictability of natural on-farm food loss. Further studies should focus on the critical analysis of variability and unpredictability of on-farm tomato loss.

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INTRODUCTION

The Food and Agriculture Organization (FAO) has defined Food loss as the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers, and consumers (Parfitt, J., Barthel, M., and Macnaughton, S., 2010) It is estimated that by 2030, global food waste at the retail and consumer levels and food losses are targeted to reduce by half per capita along production and supply chains, including post-harvest losses (United Nations, 2017) The loss will have a devastating effect on the entire global economy. Food waste is very high in middle and high-income countries at the stage of consumption while in low-income countries, food losses occur at the beginning and middle of the food chain rather than at the consumption stage. (FAO, 2017) Production processes recognize 24-30% of food loss and waste (FLW) worldwide, while post-harvest is 20% and consumption is 30-35%. (M. Kummua et al., 2012 and Lipinski, B. et al., 2013)

In low-income countries, overplanting is one of the main causes of food loss. In addition, in these low-income countries, food losses are often related to poor infrastructures such as inefficient equipment and insufficient cold storage. These risks developing countries of food insecurity. Southeast Asian countries such as Vietnam, Malaysia, Thailand, Philippines, and Indonesia see losses of fruits and vegetables between 14% and 42%. The causes of loss of productivity in the post-harvest stage are: 1) the storage process; collected during the mature and immature period and lack of caution caused wounds 2) the accelerated trim/washing process; quick washing affected the wound on the product. 3) Packaging; lost during the grading, grading, and use of low-quality packaging 4) Insufficient cold storage causes disease, 5) Shock and congestion transport, and 6) Market places; high temperature which effected to dry product. (Ubon Chinwang, 2019)

Globally, tomato is one of the largest consumed vegetables. Tomatoes are a major dietary source of the antioxidant lycopene which has been linked to many health benefits, including reduced risk of heart disease and cancer. They are also a great source of vitamin C, potassium, folate, and vitamin K(phylloquinone). (FAO, 2021). The tomato value chain in Egypt is dominated by small-scale growers using traditional growing methods on highly fragmented land plots. Up to 80 percent of the land cultivated with tomato is on plots of 5 feddans or less, with the remaining 20 percent of land categorized as medium to large-scale farms. Only a fraction of tomatoes goes to processing or exports, leaving the bulk of fresh tomatoes in the domestic distribution system that is largely informal, dominated by traders and intermediaries, and traditional in terms of technology, handling practices, and marketing methods. The challenges in the tomato value chain are directly related to high levels of quantitative and qualitative food loss. However, without applied quality standards or customer awareness about quality, the damaged tomatoes that standard donations would consider as losses tend to be sold anyway. (FAO, 2021)

In Thailand, tomato production in 2021 was around 134,084 tons with a total plant area of 39,050 rai. (Office of Agricultural Economics, 2022) Based on production statistics, the Hot District is the first large-scale vegetable farming group in Chiang Mai Province. This is the largest vegetable farm group in Chiang Mai consisting of 30 farmer members in this group, 100 rai of farming area and the main vegetable product are tomatoes, chilies, and cabbages. The previous yield per crop cycle is approximately 400 tons of chilies, 500 tons of tomatoes, and 500 tons of cabbages. The production performance of this group is around 2-3 crops cycle per year. However, the group had a lack of knowledge and resources related to technology to control greenhouse conditions, capital to invest in harvesting equipment to improve production and quality, and equipment in harvesting, storage, and improving product conditions through different processes of grading and packing. (Chiang Mai Agricultural Extension Office, 2019) Loss of production was recognized in all stages of the production process including harvesting, handling, grading, packaging, and storage of product. Thailand conducts a lot of research on-farm food loss, especially in the main agricultural production loss in vegetable production but there is limited data for estimating food loss in terms of quantity and quality. Farmers also need more knowledge, technologies, and models to identify the quantity of food loss and to prevent and reduce pre-harvest and post-harvest loss. Although many farmers realize the food loss problems, they cannot figure out how much loss occurs in each production procedure.

This study, therefore, was conducted to assess the quantity and quality of tomato food loss in farm-level production. Specifically, the study aimed at 1) identifying causes of loss in tomato production, and) quantifying the tomato losses in terms of quantity and quality at the farm level. These are very important to improve the efficiency of loss prevention and reduction in tomato production. Further, findings from this study can be used to provide information to tomato farmers on the awareness of loss in production procedures. Similarly, the findings of this study will help in developing strategies and policies for tomato handling to prevent significant tomato losses in Thailand.

MATERIALS AND METHODS

Research Method

This study used a mixed method with an exploratory sequential design. The mixed-method research methodology involves qualitative and quantitative approaches within the same study [10]. The mixed method is efficient in the integration of the qualitative and quantitative results to provide an enhanced and comprehensive answer to a research question. An exploratory sequential design is a mixed methods study design, where the quantitative phase of data collection and analysis follows the qualitative phase of data collection and analysis. (Creswell, John W., 2009)

Study area

The case study area is located in the Hot district of Chiang Mai province. The hot large-scale farming group in the Hot District is the first large-scale vegetable farming group in Chiang Mai Province. The production area is around 100 rai (or 39. 53 Acres). The previous yield per crop cycle was approximately 500 tons of

tomatoes. The production of performance of this group is around 2-3 crops cycle per year. (Chiangmai Agricultural Extension Office, 2019) Thus, this farming group is suitable for exploring food loss that occurs on farms.

Data collection and food losses assessment

Survey methodology, field visit/observation, questionnaire, in-depth interview, and focus group discussion were used to collect data on the production system of tomatoes, the links along the supply chain, and how these factors related to losses.

A semi-structured questionnaire and focus group discussion methods were used with all the members (30 people) of this farming group, which benefited to identify causes of loss in tomato production and the relationship between cause and food loss in each production process.

In the assessment of the loss in quantity and quality of tomatoes at the farm level, the study adapted the tools from C. Hanson, et al. (2016) which integrated the methods for determining the amount of food loss by direct weighing using a measuring device to determine the weight of food loss measurement methodology.

The first step explored and collected tomato loss that was found on the ground, then identified the causes of loss by symptoms in a visual and weighted mass of loss in each cause. The second step asked the farm owners to harvest the matured tomatoes that were ready for sale, then identified into 2 groups of products good quality and inferior quality weighed and recorded the mass of good quality. For the group of inferior quality, identified the causes of loss by symptoms in a visual then weighed and recorded the mass of loss in each cause.

$$\% \text{ of quantity of losses} = \frac{\text{total of unmarketable fruits weight from samples} \times 100}{\text{total weight of harvested samples}}$$

$$\text{Total loss per rai} = \text{average of productivity per rai} \times \text{quantity losses percent}$$

Quality losses, which covered the economic losses and nutrient losses, were estimated as fallow;

$$\text{Economics losses} = \text{currency of the market price per kilogram} \times \text{the weight of losses per rai.}$$

Nutrient losses were estimated using a database of tomato nutrients for reference from the Institute of Nutrient Mahidol University complied by energy, carbohydrate, potassium, and vitamin C in content per 100-gram edible portion worthy 22 kilo Cals 3.31 gram, 23 milligrams 188 milligrams, and 23 milligrams. (The Institute of Nutrient Mahidol University, 2015)

Data analysis

Statistical analysis for quantitative data was analyzed using descriptive statistics such as frequency, mean, and percentage.

Qualitative data were analyzed using the content analysis of data from in-depth interviews and focus group data. Results obtained from data analysis are used as a basis to suggest policy recommendations for loss prevention and reduction in tomato production. The summary chart in Figure 1 shows the conceptual framework of this study in Figure 1

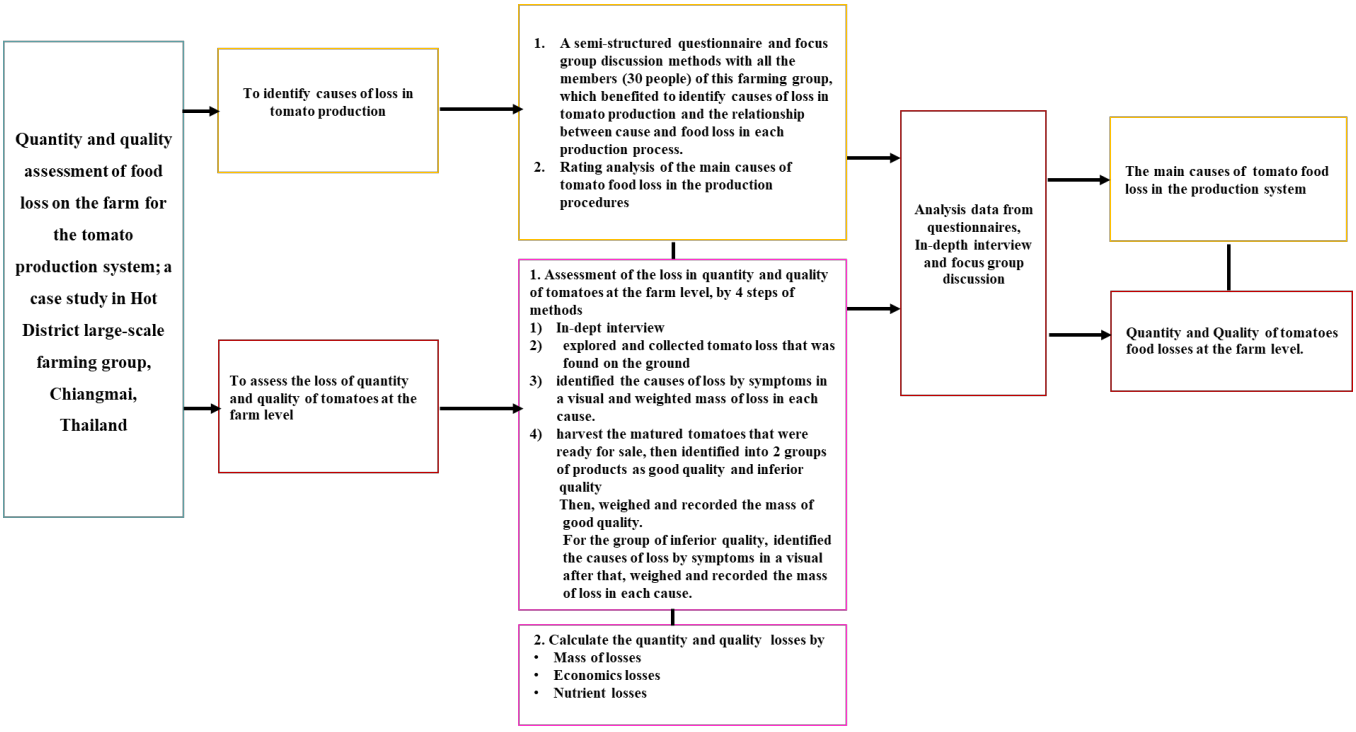

Figure 1 The flow chart of a conceptual framework of quantity and quality assessment of food loss on the farm

RESULTS AND DISCUSSION

Identify causes of loss in tomato production

Results in Table 1 and Figure 3 show the cause of farmers' practices that affected tomato losses is the weather variability the lowest level of practice by 2.083 which means to sometime practice because they rarely used some tools (e.g., hygrometer, temperature, rain gauge) to control the climate in the planting area. Moreover, the farmers had low competency to solve problems of plant growth and crop quality caused by inclement weather. Afterward, funding and funding source is the level of practice by 3.49 which means moderate practice. Eventually, the other issues namely natural disasters, cultivation and maintenance, cleanliness and standards of the collecting and packing place, production plan, farmers' knowledge, and skills, workers, diseases and pests, tools and harvesting method, cleaning and trimming of produce before packing, harvest time, sprouts or seeds, transportation of products from the farm to the collecting and packing place both of them are in a lot of practice level by 3.642, 3.859, 3.900, 3.933, 4.167, 4.200, 4.256, 4.283, 4.367, 4.383, 4.389 and 4.422 respectively.

However, from focus group discussions, farmers said, if the temperature is higher than normal, they need to put more water to balance the temperature on the field. Furthermore, the weather variability also has an effect on the aphids as spreading more quickly and are harder to control, sometimes the farmers need to destroy the crops. Figure 3 shows the main causes of identification of loss by symptoms via a visual 7 percent from disease damage, 3 percent from insect damage, and 1 percent from mechanical injured.

Quantify the tomato losses in terms of quantity and quality at the farm level

Quantity of losses assessment in terms of mass from farm level as the harvesting stage. Data presented in Table 2 show that tomato losses amounted to 6,259.459 kilograms per rai and 11.63 percent.

Table 1 The level of farmers' practices affecting tomato loss in tomato production systems.

Issues and Procedures	Level of Practice	Meaning of practice level	Std. Deviation
1. Weather variability	2.083	Sometime practice	0.740
2. Funding and Funding source	3.489	Moderate practice	0.913
3. Natural disasters	3.642	A lot of practice	0.759
4. Cultivation and maintenance	3.859	A lot of practice	0.635
5. Cleanliness and standards of the collecting and packing place	3.900	A lot of practice	0.598
6. Production plan	3.933	A lot of practice	1.009
7. Farmers' knowledge and skills	4.167	A lot of practice	0.781
8. Workers	4.200	A lot of practice	0.552
9. Diseases and pests	4.256	A lot of practice	0.611
10. Tools and harvesting method	4.283	A lot of practice	0.612
11. Cleaning and trimming of produce before packing	4.367	A lot of practice	0.865
12. Harvest Time	4.383	A lot of practice	0.916
13. Sprouts or Seeds	4.389	A lot of practice	0.714
14. Transportation of products from the farm to the collecting and packing place	4.422	A lot of practice	0.946

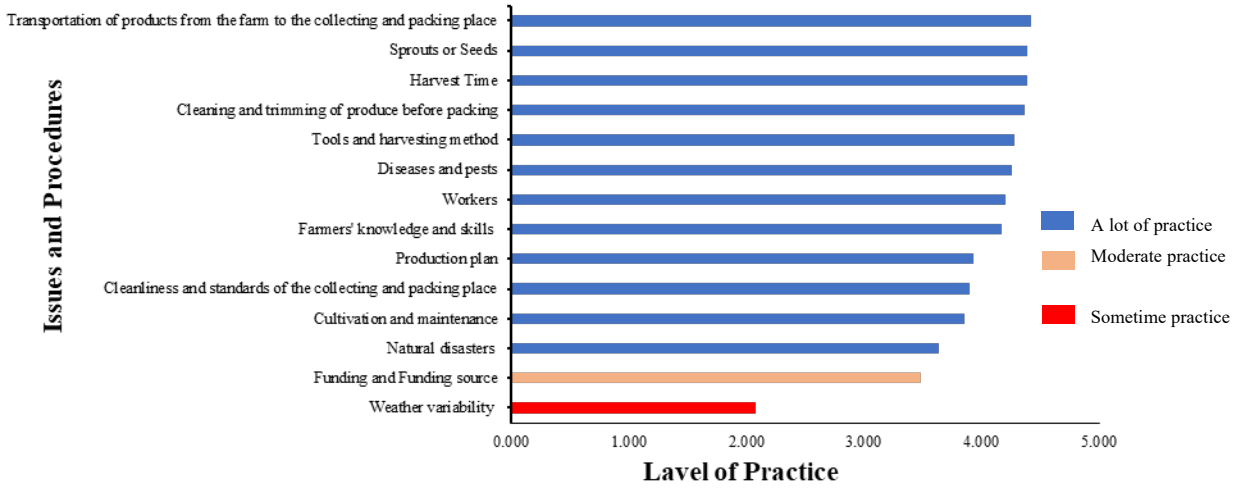

Figure 2 Identify causes of loss in the tomato production system.

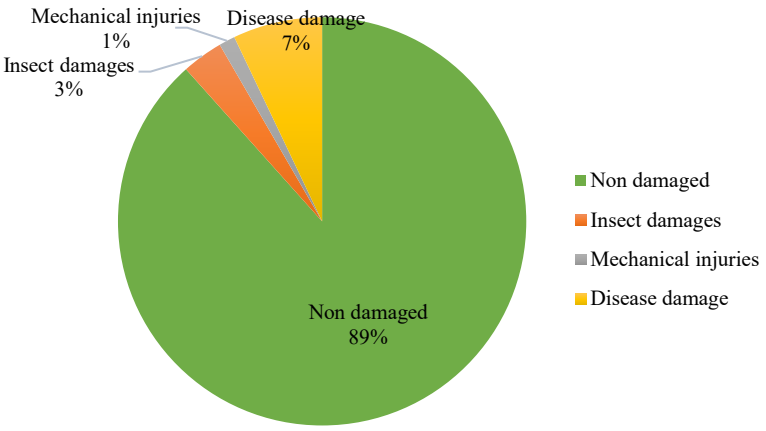

Figure 3 The identification of causes of tomato losses by symptoms via a visual at the farm level from the sample site field.

Table 2 Quantity of tomato losses

Quantity of losses	Quantity
Average yield production per rai	6,259.459 kg/rai
Total sample weight	4,592.78 kg.
Weight of losses	728.09 kg.
Percent of losses	11.63 %

Quality of the tomato losses assessment in terms of economics and nutrient. The average yield production for a rai from the table is 6,259.459 kilograms per rai and the currency of the average market price per kilogram at the Taladthai market in April 2022 (Taladthai, 2022) is 17 Bath per kilogram. The economic loss for tomatoes was approximately 12,377.60 Bath/rai.

Table 3 shows the nutrient losses assessment for 1 rai by referent the average yield production from Table 2 is 6,259.459 kilograms. The results also show that the losses were found nutrient losses in the form of energy, carbohydrate, phosphorus, potassium, and vitamin C worthy 1,377,081 kcal/rai, 207,188 gram/rai, 1,439.676 gram/rai, 11,767.784 gram/rai, and 1,439.676 gram/rai respectively.

Table 3 Nutrient of tomato losses assessment

Nutrients	Detail	Unit	Content per 100 g. edible portion	loss per rai
Energy, by calculation	Calculated by (4 x g protein) + (9 × g fat) + (4 × g CHOAVLDF) + (2 × g dietary fibre) (not include alcohol)	kcal	22	1,377,081
Carbohydrate, available	Calculated by difference: CHOAVLDF = 100 – (weight in grams [water + protein + fat + dietary fibre + ash] in 100 g food)	g	3.31	207,188
Phosphorus	AOAC method	mg	23	1,439,676
Potassium	AOAC method	mg	188	11,767,784
Vitamin C	AOAC - HPLC method	mg	23	1,439,676

Note: Average production per rai = 6,259.459 kilogram

The identification of causes of loss in tomato production farm level, the data from Figure 3 presented the cause of farmers' practices that affected tomato losses is the weather variability because they rarely used some tools to control the climate in the planting area. That study corresponds to Kanokpon Bunya-atichart (2015) who studied postharvest management and its effects on quantity and quality losses of leafy vegetables, she found the difference in losses depends on external and internal factors and the external factors include temperature, humidity, atmosphere composition, light and gravity, and pets. Choosing the best planting date, fertilizing in accordance with weather warnings, choosing the right harvest date based on weather forecasts, spraying according to the moisture conditions of the field, using suitable harvesting and transporting agricultural tools are some of the effective factors in dealing with environmental conditions. So, introducing meteorological tools and even making these tools available, teaching how to use short-term and long-term meteorological data can limit the most important factor in reducing tomato yield. The data from the field sampling shows the main causes of identification of loss by symptoms via a visual about 7 percent from disease damage, 3 percent from insect damage, and 1 percent from mechanical injured. Danai Boonyakiat et al. (2012) Studied postharvest losses of vegetables in the Royal project foundation. His result shows the main cause of loss was underutilized parts of

vegetables, insect damage, and mechanical injury. Anchan Chompupoung (2017) studied reducing the loss of vegetable productivity at the height of land fields of the Royal Project Foundation. The findings from her study revealed the causes of loss found from the farm in 3 steps. These are loss consisting of poor-quality products, infection of the disease, insects, weather variability, natural disasters, and recessive species that involve stages before harvesting. The second stage focuses on harvesting. At this stage, the product was damaged by harvesting methods and improper harvesting equipment. Also, the product shriveled due to improper harvesting time, lack of knowledge, and technology of post-harvest management. The last step is after harvest. At this stage, products were bruised due to packaging, container handling, and inefficient transportation from the farm to the packing location.

The quantitative and qualitative loss of tomatoes may affect the economic and nutritional value as well as food safety. Although many farmers realize the food loss problems, they cannot determine how much loss occurs in production procedures. In this regard, the result of this research can be applied to stimulating the farmers' awareness of losses in the production system and designing a training program for farmers to prevent and reduce loss. However, a key challenge for recovery efforts is the variability and unpredictability of natural on-farm food loss. Further studies should focus on the critical analysis of variability and unpredictability of on-farm tomato loss. Considering that weather conditions are one of the important factors in yield reduction, conducting such studies in several consecutive years, several regions and a wider statistical population can bring more comprehensive results.

CONCLUSIONS

The results, main cause of food loss in this farming group was weather variability 63.3%. The mass of tomato loss was approximately 11.63% or 728.09 kilogram/rai translating to an economic loss of 12,377.60 Bath/rai. It was also found that nutrient losses in the form of energy, carbohydrate, phosphorus, potassium, and vitamin C worthy 1,377,081 kcal/rai, 207,188 gram/rai, 1,439.676 gram/rai, 11,767.784 gram/rai, and 1,439.676 gram/rai respectively.

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