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Knowledge of Farmers on Post-Harvest Handling of Tomato in Enugu State, Nigeria

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Abstract
The study assessed the knowledge of tomato farmers in Enugu State, Nigeria. Specifically, the study determined the knowledge level and practical skills of farmers on post-harvest handling, ascertained the causes of post-harvest losses, and ascertained the constraints to tomato post-harvest handling. Four local government areas were purposefully selected for predominating IN tomato production. A structured questionnaire was used for data collection. Percentage, mean score, standard deviation, and linear regression were used for data analysis. There is a significant negative relationship between annual income from production (t = -4.306) and their knowledge of post-harvest handling. Most farmers (84.2%) had moderate skills in post-harvest handling. Excess heat (40.0%) was the main cause of post-harvest loss. The major constraints to post-harvest handling include the high cost of improved implements ($\bar{x}$ =4.75) and inadequate knowledge about post-harvest technologies ($\bar{x}$=4.43). Farmers had moderate knowledge and skills for post-harvest handling, which causes huge losses in product and profit. Adequate training should be given to farmers by the extension agents on non-tasking and cost-effective post-harvest techniques. The government should make available and accessible post-harvest technologies to farmers for improved production.

Introduction

The issue of food loss has posed a significant obstacle to global food production and supply networks, especially in many developing nations like Nigeria, and over time, this has caused a considerable decline in livelihood outcomes, such as lower household income and increased food insecurity among rural residents (Brander et al., 2020).

There are various types of vegetables produced in Nigeria, including carrots, shallots, peppers, tomatoes, sweet potatoes, potatoes, onions and okra. Nonetheless, the FAO reports that in 2017, Nigeria produced 7.2 million metric tons of various vegetables, 0.22 million metric tons of turnips and carrots, and 2 million metric tons of okra (FAOSTAT, 2021). One of the most important vegetables in Nigeria is the tomato, which is farmed and consumed by the people. There were 4.1 million metric tons of tomatoes produced in 2017. Tomatoes account for 90% of output and are a preferred crop of small-scale growers because of their large consumer base and high production volume (FAOSTAT, 2021). In addition to providing revenue for Nigerian rural farmers, the production of tomatoes contributes significantly to home food security and individual household nutrition, hence boosting farmer's livelihoods (Ajibare et al., 2022). Tomatoes are a highly beneficial crop, but their production is rendered unprofitable due to post-harvest losses. This has a negative impact on food quality, pricing, and market competitiveness (Sibanda & Workneh, 2020; Abera et al., 2020). Fresh tomatoes are predicted to lose $8.9 billion a year due to considerable post-harvest losses that result in household income losses (Oke et al., 2020).

Losses can arise at every phase and procedure, from harvesting to consumption (Abera et al., 2020; Wongnaa et al., 2023), and the underlying factors contributing to post-harvest loss have a wide range of features. Several studies have linked the post-harvest loss in tomato supply chains to quality control issues, such as the use of wooden crates for packaging, which results in undesirable compressive forces that cause internal injuries and ultimately reduce the postharvest quality of the tomatoes, or logistic issues, such as inappropriate modes of transport (Musonda & Mwila, 2024). Moreover, as per Mohan et al. (2023), the reason behind this could be the degree of knowledge that these farmers possess and how susceptible their contextual features are to post-harvest loss.

According to Kulwijila (2021), socioeconomic characteristics like age, income, gender, land size, and market type were the primary focus of other studies on the main causes of post-harvest loss in tomato supply chains. For this reason, large postharvest losses hinder tomato yield. To guarantee the quality and safety of tomatoes during their post-harvest handling, farmers must possess the necessary knowledge and abilities. This will allow them to meet the trade requirements and buyer specifications while ensuring that the vegetables are delivered to consumers on schedule.

It is on this note that this study addressed the following research questions: What is the knowledge level of farmers in the post-harvest handling of tomatoes? What level of practical skills do the farmers possess in the post-harvest handling of tomatoes? What are the causes of post-harvest losses in tomato production? What are the constraints encountered by farmers during post-harvest handling? And also understand the significant relationship between farmers' socio-economic characteristics and their knowledge level of post-harvest handling of tomatoes.

Methodology

The study was conducted in Enugu State, Nigeria. The state is located in the Southeast Geo-Political Zone of the country, lying between latitudes 5◦ 56'N and 7◦ 06'N and longitudes 6◦ 53'E and 7◦ 55'E. A multistage sampling procedure was used to select ninety-six (96) tomato farmers. In the first stage, two agricultural zones (Nsukka and Awgu) were selected through a purposive sampling technique from the six agricultural zones in the state due to the dominance of tomato farmers in the selected zones. In the second stage, two blocks were selected from each zone using a simple random technique, giving a total of four blocks. The blocks were Nsukka and Igbo-Etiti (Nsukka zone), Awgu, and Aninri (Awgu zone). In the third stage, two circles were selected from each block through a simple random sampling technique to give a total of eight circles. The circles were Eziani and Obukpa from Nsukka Block, Ekwegbe and Ozalla from Igbo-Etiti Block, Mgbowo and Akwu from Awgu Block, and Amorji and Amokwe from Aninri Block. Stage four has 12 farmers each selected through a systematic random sampling technique. Thus, the total sample size for the study was ninety-six (96).

Data was collected on socio-economic variables, including sex, age (in years), marital status (married, single, widowed, or separated), educational level (primary, secondary, or tertiary), and household size (number). The knowledge and skill were ascertained using yes and no, scored as 1 and 0 and responses were categorized based on their level of knowledge as No knowledge (0), low knowledge (0.1-0.33), moderate knowledge (0.34-0.66) and high knowledge (0.64-1) and same was adopted for skill as No practical skill (0), low practical skill (0.1-0.33), moderate practical skill (0.34-0.66) and high practical skill (0.64-1). The causes of tomato post-harvest losses were measured as yes or no. Limitations influencing post-harvest handling were measured using a 3.0-point Likert-type scale. Data were analysed using standard deviation, mean score, frequency, and percentage.

Results and Discussion

Knowledge Statements on Post-harvest Handling of Tomato

The result in Table 1 reveals that the majority (93.3%) of the respondents knew that sorting is necessary for the removal of rotten, damaged, or diseased fruits from healthy and clean ones. Fruits that are infected or damaged can generate large amounts of ethylene, which can have an impact on nearby fruits. Pokhrel (2021) stated that it is necessary to remove diseased tomato fruit to avoid contamination of other healthy fruits; if not, this will lead to contamination, which results in rotten products and post-harvest loss of tomatoes.

Table 1 indicates that the majority (92.5%) of the respondents knew that efficient and effective picking can increase the shelf life of tomatoes. According to Mohan et al. (2023), careful tomato selection extends its shelf life, but careless treatment of tomatoes during and after harvest results in low yields, waste, and financial losses for farmers. Rajapaksha et al. (2021) estimated losses for fruits and vegetable crops to range from 4–12% as a result of poor harvesting practices, including mechanical damage due to rough picking and handling in the field.

The result in Table 1 shows that the majority (90.0%) of the respondents knew that proper storage facilities help to protect tomatoes from deteriorating. Due to their high moisture content, tomatoes are exceedingly difficult to keep for an extended period at room temperature. Tomatoes can be kept for up to 7 days at room temperature. For a longer period, tomatoes can be stored at a temperature of 13°C–15°C and a relative humidity of 80–85% (Silva et al., 2021). To guarantee a steady supply of raw materials for processors, storage is typically necessary throughout the tomato value chain. Non-availability of storage facilities to local farmers implies that farmers will have to sell at reduced prices as they cannot keep the highly perishable products from deteriorating (Tongbram et al., 2021). However, in most cases, tomatoes are not stored fresh because of their high perishable nature.

Entries in Table 1 show that the majority (83.3%) of the respondents indicated that for short-term storage (up to a week), tomato fruits can be stored at room temperature provided there is enough ventilation to reduce the accumulation of heat from respiration. Rutta (2022) stated that the majority of tomato farmers in Tanzania stored their vegetables under normal temperature conditions. This research revealed that the majority of farmers spread tomatoes on the floor of the room while leaving the windows open to allow for cross-ventilation. Respondents stated that this helps prolong the shelf life of tomatoes.

The result in Table 1 shows that the majority (82.5%) of the respondents knew that pre-cooling after harvesting was necessary for the increased shelf life of tomatoes. This finding agrees with Makule et al. (2022), who found that most of the tomato farmers in Taraba State do not package tomatoes immediately after harvest but leave them for some time to cool. When many fruits and vegetables are ready for harvest, field heat is typically high and undesired. It should be eliminated as soon as possible before beginning any postharvest handling activities (Makule et al., 2022).

Table 1 reveals that the majority (82.5%) of the respondents also knew that using smooth surfaces and shallow containers would prevent overloading, thereby reducing mechanical injuries to the harvested tomato. According to the respondents, the use of the “happy family” bowl is a result of the smooth surface, which prevents tomatoes from spoilage, especially during transportation. Njilar et al. (2023) noted that packaging containers with sharp edges must be discouraged to avoid bruising and puncturing of the produce.

Table 1: Knowledge statement on post-harvest handling of tomato

Knowledge statement on post-harvest handling	(%)
Sorting	**93.0**
Effective picking	92.0
Proper storage facilities	**90.0**
Short-term storage	**83.0**
Pre-cooling	82.5
Smooth surface	82.5
Optimum temperature	**80.0**
Overloading	76.7
Proper packaging during transportation	**76.7**
Ambient temperature during storage	**65.0**
Use of oversized basket	64.2
High temperature induces deterioration	**61.7**
Use of tree shades	60.0
Storage extends the length of the processing seasons	56.7
Packaging helps protects tomatoes	55.0
Woven basket is very harsh with harvested tomatoes	**40.8**
Low temperature destroy the shelf-life of tomatoes	**47.5**
Improper packaging causes mechanical damage	**20.0**
Refrigerated vehicles preserves tomato quality	7.5

Table 1 reveals that the majority (80.0%) of respondents agreed that the optimum temperature for tomato harvesting is about 20 °C and can be attained either in the early hours of the morning or late in the evening. Most of the respondents stated that they pick tomatoes in the morning or evening, which implies that they realize the importance of harvesting tomatoes in the morning or evening for an increase in the shelf life of tomatoes. According to Firdous (2020), the time of tomato picking is considered the most important factor in post-harvest losses as well as deterioration of quality.

Table 1 reveals that the majority (76.7%) of the respondents knew that overloading during harvesting can cause the buildup of excessive compressive stresses, resulting in the crushing of fruits that are found at the base of the containers. Before the use of bowls, most of the produce spoiled along the way because of compression between the baskets, which caused the food to be crushed before it got to its destination. A study by Joseph, Bunyatta, and Langat (2021) found that most of the respondents place their produce on top of each other and make a huge heap, which leads to spoilage of produce at the bottom due to the high heat generation.

According to Table 1, the majority (76.7%) of respondents were aware that in order to minimise excessive movement or vibration during transit, the produce should be immobilised by adequate packing and stacking. According to Tkaczyk and Szpotaski (2023), physical damages might occur during transit due to package sizes (big bags), vehicle overloading, and unsuitable packing materials, resulting in excess vibration.

Similarly, Table 1 reveals that a larger number (65.0%) of respondents were aware that preserving tomatoes at low temperatures can improve their texture, nutrition, flavour, and aroma. According to Chen et al. (2020), correct temperature management throughout tomato ripening and storage is crucial to sustaining quality.

Table 1 shows that a greater proportion (64.2%) of the respondents knew that an oversized woven basket results in excessive crushing forces on tomatoes located at the base of the basket. According to Adepeju (2014), inefficient packaging of produce during transportation results in excess crushing of tomato fruits at the base of the basket as they are usually heaped on top of one another.

Entries in Table 1 show that a greater proportion (61.7%) of the respondents knew that high temperature induces deterioration of tomatoes. Tao et al., (2021) stated that tomatoes deteriorate easily in transit and storage, especially under conditions of high temperature and humidity.
Koza (2022) found that tomatoes in Turkey suffered losses owing to exposure to dire ct sunlight after harvesting. Heat and hot weather increase on-
arm losses in tomatoes.

The data presented in Table 1 indicates that a higher percentage of respondents (60.0%) were aware that tree shadows are not dependable for shielding tomato since they tend to move away from the produce when the sun shifts its position. Tree shades are unreliable, according to Moerman (2023), since they tend to move away from the produce when the sun moves. This exposes the fruits to the hot sun, which builds up field heat on the food.

According to Table 1, about half (56.7%) of the respondents were aware that storage contributes to the extension of the processing season and ensures a consistent supply of products across the seasons. Storage is typically necessary to guarantee processors have a steady supply of raw materials; storage procedures help lengthen the processing season and guarantee product supply continuity in all seasons (Ochida, et. al., 2019).

Table 1 shows that about half (55.0%) of the respondents knew that packaging can help protect tomatoes from contamination from physical, chemical, and biological sources. This finding corroborates that of Moerman (2023) that tomato farmers agree that packaging had the highest potential of reducing postharvest losses but that the majority of farmers do not perform potential postharvest handling activities mainly due to insufficient knowledge and skills. These results demonstrate the respondents' familiarity with various post-harvest handling techniques. Their understanding of post-harvest procedures may enable them to handle the commodity better after harvest, increasing their revenue. It is noteworthy that a sizable portion of the respondents lacked knowledge of contemporary post-harvest handling technologies, such as the use of polyvinyl chloride, methyl cyclopropane, and modified environment packaging. This necessitates raising tomato growers' understanding of the procedures and training them in their execution.

Knowledge level on post-harvest handling of tomato

The majority (86.6%) of the respondents had high knowledge of post-harvest handling of tomatoes, while 6.7% had low knowledge and 6.7% had moderate knowledge (Figure 1). This shows that respondents had a high understanding of how to handle tomatoes after harvest and are capable of incorporating this knowledge into their practices to handle tomatoes better. According to Njenga, (2021), the knowledge level of farmers is influenced by many factors ranging from age, educational level, years of farming experience, farm size, and belonging to farmer’s groups which plays a key

role to persuading farmers to share challenges, try new technologies and exchange new information.

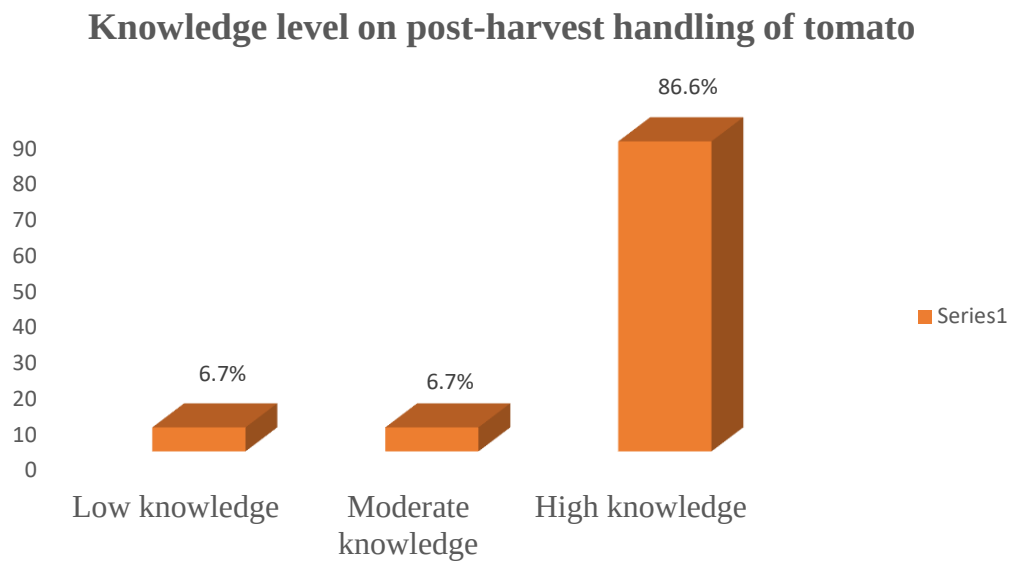

Figure 1: Knowledge level on post-harvest handling of tomato of tomato

Level of Practical Skill of Farmers in Post-Harvest Handling of Tomato

The majority (84.2%) of the respondents had moderate skill in post-harvest handling (Fig 2), while 9.2% had low skill and 6.7% had high skill. The farmers' moderate post-harvest handling skills indicate that they needed to increase their abilities to lower tomato post-harvest losses. Farmers would lose more due to spoilage if they do not practice good post-harvest handling. According to Despoudi, (2021), food losses are mainly due to lack of technology, insufficient skill, and knowledge and management capacity of farmers. A study conducted by Mohammed and Usman (2023**)** revealed the implication of post-harvest losses of vegetables on pushing farmers into financial deficit which could negatively impact both farmers' and distributors' income which translates to wastage of energy and resources deployed for production.

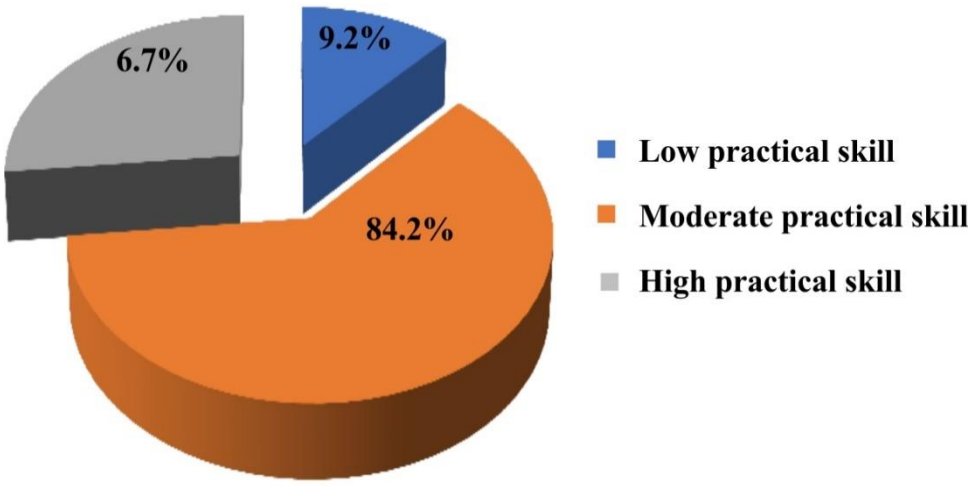

Figure 2: Level of practical skill on post-harvest handling

Causes of Post-Harvest Loss of Tomato

Results in Table 2 show that a higher percentage of respondents (40.0%) thought that excessive heat was the primary reason why tomatoes lose their quality after harvest. According to Kumar (2020), high temperature causes biological processes like respiration and metabolism in fruits and vegetables to increase. The findings reveal that 38.3% of respondents claimed that excessive humidity and washing of produce before selling results in post-harvest loss; 32.5% claimed that pests were the cause, and 15.0% claimed that diseases were mainly the cause of post-harvest loss. Lufu et al. (2020) states that high crop perishability, mechanical damage, and prolonged exposure to high temperatures, relative humidity, and rain are the main physiological, physical, and environmental causes of post-harvest losses. Contamination by bacteria and fungi can also result from improper handling, storing, and processing techniques, as well as pest infestations including rats, birds, and insects.

Table 2: Causes of post-harvest loss of tomato

Causes of post-harvest loss of tomato	Frequency	Percentage
Excessive heat	48	40.0
High humidity and cleaning with water	46	38.3
Pests	39	32.5
Disease	18	15.0
Inadequate storage/processing facilities	15	12.5
Poor transit and road network	14	11.7
Excessive packing	13	10.8
Improper sorting	12	10.0
Inappropriate handling	11	9.2
Inappropriate ventilation	11	9.2
Injury of crop	9	7.5
Improper/premature harvesting	6	5.0
Poor storage and short shelf life	5	4.2
Inadequate market materials	5	4.2
Excessive use of chemicals and inorganic manure	4	3.3
Over shades	2	1.7
Untimely harvest	2	1.7

Table 2 shows that 12.5% of respondents reported inadequate storage/processing facilities, 11.7% poor transit and road network, 10.8% excessive tomato packing, 9.2% poor ventilation, 9.2% inappropriate handling, and 7.5% crop injury. Furthermore, 5.0% showed improper/premature harvesting, while 4.2% indicated long storage and a short shelf life. According to Debebe (2022)**,** poor infrastructure, harvesting methods and post-harvest handling procedures aggravate post-harvest loss. Additionally, Anyaoha et al (2023) discovered that post-harvest loss is caused by injuries brought on by bad handling, illnesses, and pest attacks. The respondents stated that while farmers deal with issues like birds and rodents throughout the year, they have just lately begun to deal with snail invasions on tomato plants.

Constraints to Tomato Post-Harvest Handling

Results in Table 3 show that the major constraints affecting tomato post-harvest handling were: high cost of improved implements ($\bar{x}$=4.75), inappropriate knowledge

about post-harvest technologies ($\bar{x}$=4.43), unavailability of technical advice (extension services) ($\bar{x}$=4.34), lack of storage facilities ($\bar{x}$=4.07), unavailability of labour ($\bar{x}$=3.77), inadequate transport facility ($\bar{x}$=3.27) and inadequate knowledge on application of right timing of harvesting ($\bar{x}$=3.06) were all considered as the causes of post-harvest losses in tomato. High cost of improved implement deters farmers from using them hence leading to high production losses. Furthermore, according to Hussein et al. (2020), in developing countries, postharvest handling techniques for fruits and vegetables, such as enhanced storage, packaging, transport, and handling methods, were essentially non-existent for perishable crops in most regions. If they were, they were difficult for indigenous populations in the production areas to access, which resulted in significant produce losses. The unavailability of technical advice (extension services) implies that extension services have not been an effective means of obtaining information for the tomato farmers. This is consistent with Ohagwu et al. (2024) who noted that a lack of access to extension services was a key obstacle which limit farmers knowledge acquisition on some good agricultural practices for increased production.

Table 3: Constraints to tomato post-harvest handling

Constraints	Mean ($\bar{x}$)	SD
High cost of improved implements for post-harvest handling	4.75	0.54
Inappropriate knowledge about post -harvest technologies	4.43	1.03
Unavailability of technical advice	4.34	1.02
Subsidy is not given on different agricultural Inputs	4.34	1.15
Lack of storage facilities	4.07	1.41
Inadequate knowledge and skills about proper methods of tomato production	3.77	1.28
Inadequate knowledge about proper application methods of chemicals	3.70	1.27
Absence of assured insurance facility	3.39	1.61
Inadequate transport facility.	3.27	1.61
Inadequate knowledge and application of the right timing for Harvesting	3.06	1.58
Absence of assured marketing	2.78	1.28
Tomato markets are too far	2.64	1.47
Poor transport network	2.33	1.26

Relationship between Socio-Economic Characteristics of Farmers and Knowledge Level of Post-Harvest Handling of Tomato

Table 4 shows the result of the multiple linear regression on the effect of socio-economic characteristics of respondents on their knowledge level of post-harvest handling of tomatoes. Results show that there is a significant negative relationship between annual income from tomato production (t= -4.306; P≤ 0.05) and their knowledge of post-harvest handling of tomatoes. This means that the more the income of the respondents, the less their knowledge of post-harvest practices in tomato production. The implication of this finding indicates that low knowledge of post-harvest practices leads to high income of farmers and hence increase in quantity produced. and sold. These data are contrary to the conclusion reached by Sani et al. (2023), that the overall value of postharvest losses has a detrimental impact on tomato growers'

per-capital income and thus welfare. According to the modified R^2, income accounted for 16.9% of the variation in respondent's knowledge of post-harvest practices.

Table 4: Relationship between the socio-economic characteristics of farmers and their knowledge level of post-harvest handling

	Unstandardized Coefficients		Standardized Coefficients	
Variables	**B**	**Std. Error**	**Beta**	**T**
1 (Constant)	0.468	0.084		5.601
Sex	0.036	0.030	0.129	1.205
Age	-0.002	0.001	-0.227	-1.847
Marital status	0.000	0.032	0.001	0.007
House hold size	0.008	0.006	0.144	1.374
Educational level	0.018	0.044	0.047	0.419
Farm experience	0.003	0.002	0.199	1.686
Estimated Tomato income	1.360E-7	0.000	-0.440	-4.306**
Tomato farm size	-0.009	0.026	-0.034	-0.325
Produced quantity	-0.001	0.001	-0.171	-1.238
Loss quantity	0.001	0.003	0.067	0.519

**** P≤ 0.05**

Conclusion and Recommendations

Tomato wastage/loss is as a result of lack of storage facilities and lack of knowledge on the simple techniques for tomato preservation which discourages the farmers after channelling all their limited resources to production. The weather-related factors that contribute to tomato post-harvest loss include high humidity, excessive heat, pests and diseases, and inadequate ventilation. Governments should provide farmers with access to some post-harvest technologies in order to increase production. Extension agents should also teach farmers low-cost, low-task post-harvest techniques so that farmers can manage their crops more efficiently. Governments should build a marketing structure for tomato farmers and also build industries/processing factories for tomatoes, thus encouraging farmers to cultivate more.

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