
Working Paper Series

This working paper forms part of the ACIAR Project AGB/2012/061
*Improving smallholder farmer incomes through strategic market
development in mango supply chains in southern Vietnam*

Study: 2.4 Partial Freezing Trial

Date: 26 November 2020

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Summary

Freezing in bulk is a commonly used system to manage large volumes of seasonal crops. The technique enables manufacturers to maximise raw material by postponing processing until after the main season. This maximises the use of fresh produce, reduces the prospect that expensive processing equipment will remain idle, reduces waste, and optimises return income for growers. The system is not widespread within the Vietnam mango industry, and this small-scale comparative study represents the first stage in developing best practice, leading eventually to a Code of Practice.

Samples of mangoes were peeled and divided into two subsets. One subset was frozen 'stone-in' and the second with the stone removed. They were frozen to a core temperature of minus 18°C and then thawed, homogenised, and subject to sensory assessment using a Hedonic scale. There was no significant difference in the eating quality of the mangoes from each subset. This is noteworthy because processors now have the option of peeling (mechanically) and destoning by centrifugation or pressure sieving—two inexpensive options compared to the more expensive option of destoning by hand.

There was a statistical difference, observed in both subsets, between the perception of mango quality by assessors from the processing enterprise (Long Yuen Co) and the project assessors. It is recommended that, for future development work, mango quality evaluation should align more closely with commercial sensory standards, using a more descriptive method of assessment.

The difference in quality between those mangoes selected for trial by Long Yuen Co staff and those provided by a collector from My Tho Tien Giang province is tangible. However, the experiment was commissioned at season decline, and availability of mangoes was limited. This indicates that sensory characteristics may be the germane index of quality deterioration and warrants further, sequential investigation. It is anticipated that greater volumes of mangoes can be processed if these techniques are implemented. Therefore, collection of economical volumes of mango stones at a low cost should emerge. Mango stone oil is an institutional item offered by most online marketing sites and has demonstrably high value. Rudimentary costs were assessed (in the event that the system was implemented) but were confined to this trial. More extensive cost-benefit analyses will be possible by inclusion of more processors.

Based on the result from these trials, the following recommendations are made:

- The sample sizes used in these trials were small, and statistical analysis would be more rigorous if applied to repeat trials with larger numbers of samples.
- That the discrepancy between mango sensory properties recorded by SIAEP and Long Yuen Co assessors is addressed, possibly with reference to the Mango Quality Assessment Kit.
- There is a clear drop in sensory quality between the two trials—possibly relating to handling, age, or over-maturity given the timing of this project. However, this signals the value that sensory testing can have on assessing deterioration. It is recommended that this is investigated using time/sensory evaluations.
- The trials reported here are small and barely representative of issues that relate to mango quality partial processing and degree of maturity. It is recommended that trials are repeated to test trends and economic imperatives, including up to 15 other processors.
- That the work is directed towards the preparation of a recommended Code of Practice.

Context

Introduction

A dilemma facing all processors of highly seasonal crops is that fixed costs must be recovered from overwhelming volumes of raw materials that are only available for short periods. Facilities and personnel work at capacity during this period. This is particularly the case for mangoes, which are produced in prodigious volumes at season height. Mangoes are also highly perishable. Partial processing at season surfeit for on-processing, as supplies dwindle, can reduce waste and optimise the use of expensive equipment that would otherwise lie idle.

This trial is the first stage in the development of a series of procedures recommended in a code of practice that will be available to processors that would enable them to:

- Maximise the use of high-season mangoes
- Reduce waste
- Extend the use of factory facilities, including expensive equipment
- Augment the demand for mangoes, leading to increased return for farmers' effort

The first part of this trial was undertaken at the Long Yuen Company commercial premise. This added commercial relevance to the trial and was a vector to prepare SIAEP staff to duplicate techniques for times when the factory is unavailable. A second trial was conducted at the SIAEP facility to assess reproducibility, so that future trials can be conducted at the same premises. This would release the activity from private sector dependency, while maintaining relevance. Canvassing a wider section of the processing sector will be an imperative as the project matures. This will enable the design of a standard operating procedure in the form of a Recommended Code of Practice.

Damage incurred during freezing depends on the speed with which heat can be withdrawn from tissue as the temperature drops through the freezing range—minus 0.5°C to minus 5.5°C. Damage is manifest by the amount of fluid that exudes from the fruit as it thaws—so called 'drip-on-thaw'. Once the temperature reaches minus 18°C, few changes take place. Samples can be thawed for evaluation at any stage after that. In order to meet time constraints, the samples were withdrawn after one week.

However, the freezing process damages soft tissue which is caused by mechanic rupturing of membranes and shifting electrolyte pH in the intracellular fluid. The techniques therefore limit the end-use of the thawed frozen flesh, which is then limited to such products as purees, conserves, and confections. The ultimate decision to adopt this procedure will be based on the financial balancing of waste reduction and extended use of high-cost equipment against costs of bulk handling of incoming mangoes and additional electricity use. The extent of damage during freezing is indicated by the damage to the cellular integrity of fruit. The fluid that leaves the sample when it is thawed (so-called drip-on-thaw) is related to freezing efficiency. In any event, this drip will be added back to the pulp for subsequent processing, but the volumes involved are a useful quality control indicator.

Activities

The techniques for handling incoming mangoes were demonstrated to, and subsequently adopted by, SIAEP staff using the facilities provided by Long Yuen Co Ltd. This trial was repeated in its entirety, using mangoes purchased on the open market.

The repeated experiment was used to estimate reproducibility of the procedure and to enable SIAEP staff to determine appropriate quality for future trials independent of input from Long Yuen Co. This suggests the need for more extensive trials involving a selected number of alternative processors (perhaps up to 15 others).

The following activities were undertaken in this trial:

- 200 samples, considered to be satisfactory by evaluators at Long Yuen Co Ltd, were selected.
- The selected mangoes were Brix 15.1°.
- The average mass of mangoes was 337g.
- Mangoes were soaked in a solution containing 200 ppm free chlorine solution for 10 minutes.
- Mangoes were drained and soaked for 10 minutes in a solution containing 0.6% ozone for 10 minutes.
- Mangoes were peeled and divided into two (approximately equal) sub-samples.
- Skins, flesh, and stone weights were recorded.
- One sub-sample was simply packaged and frozen (N series). The other was destoned, packaged, and frozen (M series).
- Samples and sub-samples were weighed at every stage to assess losses.
- Samples were frozen at minus 18°C and retained until the temperature had equilibrated (5 days).
- Samples were thawed at ambient temperature and the drip-on-thaw was weighed.
- Samples were recombined and subject to sensory assessment using 10 evaluators from SIAEP and Long Yuen Co.
- Samples were assessed using a seven-point hedonic scale for appearance, taste, appearance, and overall acceptability.
- The thawed mango pulp and juice were recombined and blended to ensure uniformity for each sample.
- They were then subjected to taste panel evaluation using the seven-point hedonic scale for appearance, aroma, taste, and overall acceptability.
- Because the sample sizes were small, JMP 9.02 software was selected as the most appropriate statistical analysis to establish significance in sensory qualities between the two treatments.
- Using JMP 9.02 software, the results were statistically analysed to establish a significant difference between the SIAEP evaluators and the evaluators from Long Yuen Co.
- Limited costs were collected in order to gauge financial viability of the procedure.
- The entire procedure was repeated using mangoes purchased on the open market and originating from My Tho Tien Giang Province.

Results and discussion

Mango composition

Table 1. Mango components (Trial 1)

	Quantity	Whole fruit (kg)	Peel (kg)	Whole flesh (kg)	Flesh without seed (kg)	Seed (kg)	Flesh without seed/ whole fruit (%)	Peel/ whole fruit (%)	Seed/ whole fruit (%)
Total fruits	191	64.34	16.33	48.01					
Sample 1	80	26.81	6.84	19.97					
Sample 2	111	37.58	9.49	28.09	20.88	7.21	56	25	19

Table 2. Mango components (Trial 2)

	Quantity	Whole fruit (kg)	Peel (kg)	Whole flesh (kg)	Flesh without seed (kg)	Seed (kg)	Flesh without seed/ whole fruit (%)	Peel/ whole fruit (%)	Seed/ whole fruit (%)
Total fruits	197	62.95	9.15	53.80					
Sample 1	99	31.90	4.60	27.30					
Sample 2	98	31.05	4.55	26.50	21.90	4.60	70	15	15

Table 3. Drip-on-thaw (Trial 1)

Sample	Whole sample (kg)	Mango flesh without seed (kg)	Thawed water (kg)	Drip-on-thaw (%)
N1	10.01	7,474	1.611	21.6
N2	9.96	7,437	1.368	18.4
M1	10.05	10.05	1.592	15.8
M2	10.03	10.03	1.820	18.1

Table 4. Drip-on-thaw (Trial 2)

Sample	Whole sample (kg)	Mango flesh without seed (kg)	Thawed water (kg)	Thawed water/ mango flesh (%)
N1	10.0	8.2	1.40	16.9
N2	9.9	8.2	1.31	16.1
M1	10.0	10.0	3.02	30.2
M2	10.0	10.0	3.06	30.6

Findings included the following:

- Mango composition was consistent in both trials, with the stone weighing between 15 – 19% of the stone.
- No statistically significant difference (95% confidence interval) was observed between the sensory scores for the evaluation of appearance, aroma, taste, and overall acceptability between the two frozen methods. This observation was confirmed in both trials.
- There was a statistically significant difference (95% confidence interval) when comparing the sensory scores for evaluation criteria such as appearance, taste, and overall acceptability between group assessor SIAEP (A1, 2, 3, 4, 5, 6) and group assessors at Long Yuen Co (A8, 9, 10). However, there was no statistically significant difference (95% confidence interval) when comparing the sensory scores for evaluation criteria 'aroma' between group assessors from SIAEP (A1, 2, 3, 4, 5, 6) and group assessors from Long Yuen (A8, 9, 10).
- There was a significant difference between the sensory characteristics of the mangoes selected by the Long Yuen Co and those supplied by the collector from My Tho Tien Giang Province.
- In Trial 2, one sample had a high drip-on-thaw loss. It was frozen using the commercial freezer and took an excessively long time to freeze.
- Rudimentary costs have been included at Appendix 2, but these are based on scant information. Therefore, other factors such as greater utilisation of equipment and facilities and reduction in waste must be included before a complete cost/benefit analysis can be completed.

Insights

The key insights from this trial were:

- A salient insight from these trials is that there is no significant difference in sensory attributes between freezing stone-in and freezing after stone removal. The purpose of the second trial was to reaffirm the trial protocol and to confirm that there was no significant difference between mangoes frozen stone-in and those frozen after stone removal. Mechanical peeling is justified if incoming mangoes are in sufficient quantities, so that large volumes can be handled in a short time.
- As the flesh loses its turgor as a result of freezing, it is anticipated that the stone would be easier to remove from the flesh, either by pressure sieving or centrifugation. Once again, there are options for bulk handling. Therefore, whole peeled mangoes (perhaps mechanically peeled) can be frozen stone-in with confidence. However, the mass of product is higher, and freezing is therefore slower, if the stone is included. Further, storage requirements are marginally higher.
- The hedonic scale was used to evaluate differences between the two processing protocols because this was a simple comparative assessment. A significant difference was observed between the panel scores given by SIAEP team members and those given by the Long Yuen Co counterparts, who are less tolerant of substandard mangoes. This suggests the need for greater dialogue on quality determination, with reference to the more detailed characteristics described in the ACIAR Mango Quality Assessment Kit.
- Drip-on-thaw is not pertinent to the final economic analysis, because it is recombined after weighing. It is, however, a useful quality assessment measure because it is a measure of damage to the cellular tissue, which is dependent on the rate of cooling through the freezing range (Trial 2, M1 and M2). However, the very slow freezing time may result in enzymic browning and variation in moisture during on-processing.
- The economics of stone recovery depends on collecting large volumes at a single collection point. Mango kernel contains about 15% of good quality, edible oil that is comparable to

soybean and cottonseed (which contain about 18 – 20 % oil). Mango kernel oil (MKO) has lower free fatty acids, carotenoid content, and peroxide value, and is usually used without any processing, which is otherwise mandatory for commercial vegetable oils.¹

The following recommendations are made:

- The sample sizes used in these trials were small, and statistical analysis would be more rigorous if applied to repeat trials with larger numbers of samples.
- It is recommended that the discrepancy between mango sensory properties recorded by SIAEP and Long Yuen Co assessors is addressed, possibly with reference to the ACIAR Mango Quality Assessment Kit.
- There is a clear drop in sensory quality between the two trials, possibly relating to handling, age, or over-maturity given the timing of this project. However, this signals the value that sensory testing can have on assessing deterioration. It is recommended that this is investigated using time/sensory evaluations.
- The trials reported here are small and barely representative of issues that relate to mango quality partial processing and degree of maturity. It is recommended that trials are repeated to test trends and economic imperatives, and to include up to 15 other processors.
- That work is directed towards the preparation of a recommended Code of Practice.

¹ Nadeem, M, Imran, M and Khaliq A., (2016) Promising features of mango (*Mangifera indica* L.) kernel oil: a review. *Journal of Food Science Technology*. 53(5): 2185–2195.

Appendices

1. Trial 1 – Thawed frozen mango sensory scores

Samples	Evaluation criteria	Score										Ave
		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	
N1	Appearance	2	2	2	3	4	3	5	7	6	7	4.1
	Aroma	7	4	4	4	6	5	6	6	6	7	5.6
	Taste	6	4	1	4	5	4	3	6	6	6	4.5
	Overall acceptance	5	3	3	5	4	4	3	6	6	6	4.5
N2	Appearance	2	3	3	4	3	3	3	6	6	6	3.9
	Aroma	7	5	5	5	6	5	4	6	6	6	5.5
	Taste	6	3	3	5	5	4	3	6	6	6	4.7
	Overall acceptance	5	3	3	5	4	4	3	6	6	6	4.5
M1	Appearance	3	3	3	4	2	4	4	6	6	6	4.1
	Aroma	7	5	5	5	6	5	3	6	6	6	5.3
	Taste	6	4	2	5	5	4	3	6	6	6	4.7
	Overall acceptance	5	5	3	6	4	5	4	6	6	6	5.0
M2	Appearance	3	3	3	4	2	4	4	6	6	6	4.1
	Aroma	7	5	5	4	6	5	5	6	6	6	5.5
	Taste	6	4	2	5	6	5	3	5	5	5	4.6
	Overall acceptance	5	5	3	5	4	5	4	6	6	6	4.9
	Mango eating habit											
	Do you eat mangoes?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
	How often do you eat it?											
	- Every day											
	- How many times a week?							2				
	- How many times a month?	3	20	1	3-4	2-3	1-2					

2. Trial 2 – Thawed frozen mango sensory scores

Sample	Evaluation criteria	Score										Ave
		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	
N1	Appearance	1	1	2	1	1	3	2	2	1	1	1.5
	Aroma	5	4	5	4	4	4	4	4	4	4	4.2
	Taste	5	4	2	4	4	5	3	3	3	3	3.6
	Overall acceptance	3	3	1	5	5	4	3	2	2	2	3.0
N2	Appearance	1	1	2	1	1	3	2	1	1	1	1.4
	Aroma	5	4	5	4	4	4	4	6	6	6	4.8
	Taste	5	4	2	4	5	5	4	6	5	6	4.6
	Overall acceptance	3	3	1	5	5	4	3	3	3	3	3.3
M1	Appearance	2	1	2	1	1	3	3	1	1	1	1.6
	Aroma	5	4	5	5	4	4	3	4	4	4	4.2
	Taste	5	3	2	5	4	4	2	3	3	3	3.4
	Overall acceptance	2	2	2	4	4	4	3	2	2	2	2.7
M2	Appearance	2	1	2	1	1	3	3	1	1	1	1.6
	Aroma	5	4	5	5	5	4	3	3	3	3	3.9
	Taste	5	4	2	4	5	4	3	2	2	2	3.3
	Overall acceptance	2	2	2	5	5	4	3	1	1	1	2.6
	Mango eating habit	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
	Do you eat mangoes?											
	How often do you eat it?											
	- Every day											
	- How many times a week?							2	1			
	- How many times a month?	3-4	20	1	1-2	3-4	1-2				(*)	(**)

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