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# A comparative study of the local and overseas fermentation methods using Trinitario cocoa variety in Samoa

Technical Report 104

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Prepared by

**AECOM Services Pty Ltd**
Level 28, 91 King William Street, Adelaide SA 5000, Australia
T +61 8 7223 5400 F +61 8 7223 5499 www.aecom.com
ABN 46 000 691 690

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Job No.: 42444251

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# Acknowledgement

The Scientific Research Organisation of Samoa (SROS) expresses its appreciation to the Pacific Horticultural and Agricultural Market Access Program (PHAMA) for the funding support which has allowed this critical study to be undertaken to assist the efforts for revitalizing the cocoa industry.

The SROS also acknowledges the support of its partners namely the cocoa farm owners, Melzi Plantation and Kolone Vaai, as well as Terry and Stephanie Everitt of Devonport Chocolates for sharing their invaluable experiences and technical know-how.

# 1.0 Introduction

The Government of Samoa (GoS) has made it a priority to revitalize the cocoa industry along with coconut and coffee under its stimulus package scheme operated by the Ministry of Agriculture and Fisheries (MAF). The SROS"s role is to assist with value adding options to ensure farmers receive value for money which also provides the incentive necessary to continually produce cocoa as a cash crop.

Samoa is renowned worldwide for its high quality cocoa and it is unfortunate the industry has been very slow to recover from the devastating effects of past cyclones. The industry's revival is dependent on the farmers' collective ability to provide a consistent supply of quality cocoa beans to service the domestic and particularly the export market.

To assist this revival, the SROS with the assistance from the Australian-funded Pacific Horticultural & Agricultural Market Access Program (PHAMA) is currently undertaking a comparative study of the local fermentation method and a proven method from overseas - with the overall aim of improving the quality of cocoa intended for export through the fermentation process.

This report will detail the study conducted starting with some background information. It will then discuss the objectives, study methodology used, results achieved and conclusions with recommendations for future work.

# 2.0 Background

Cocoa (Theobroma cacao) used to be one of the major export commodities for Samoa until the early 1990"s when the industry was substantially destroyed by Cyclones Val and Ofa. Although it made slow progress to re-establish itself in the export scene with production of small cocoa products like "koko samoa", there was no cocoa export for 12 years from 2003 until early 2015, as shown in Table 1.

**Table 1. Export by commodity, values in thousands of tala (SAT$)**

| During period | Jan 03 | Jan 04 | Jan 05 | Jan 06 | Jan 07 | Jan 08 | Jan 09 | Jan 10 | Jan11 | Jan 12 | Jan-13 | Jan-14 | Jan-15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **OTHER EXPORTS** | | | | | | | | | | | | | |
| **Others, of which** | **32** | **11** | **25** | **11** | **107** | **5** | **29** | **10** | **13** | **5** | **13.8** | **6.7** | **83.0** |
| of which: | | | | | | | | | | | | | |
| Lotion | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 |
| Soaps | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| Banana | 9.8 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.5 | 5.4 | 5.1 |
| Taro Palagi | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Ava | 2.3 | 4.2 | 0.0 | 4.3 | 1.7 | 0.0 | 0.3 | 0.0 | 0.7 | 0.0 | 0.3 | 0.0 | 0.0 |
| Giant Clams | 0.4 | 3.0 | 8.4 | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Taamu & Yams | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 2.3 | 2.4 | 1.8 | 0.0 | 0.0 |
| Timber | 1.0 | 1.2 | 3.0 | 2.5 | 2.7 | 3.3 | 3.4 | 1.9 | 1.3 | 2.1 | 0.8 | 0.0 | 0.0 |
| Vegetables | | | | | 2.7 | 3.3 | 3.4 | 1.9 | 1.3 | 2.1 | 0.8 | 0.3 | 0.3 |
| Breadfruit | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Body care | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cocoa pods | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 |
| Palusami | - | - | - | - | - | - | - | - | - | - | - | - | 0.0 |
| Coco beans | - | - | - | - | - | - | - | - | - | - | - | - | 55.9 |
| Flour | - | - | - | - | - | - | - | - | - | - | - | - | 0.0 |
| Coconut leaves | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Chilli Sauce | - | - | - | - | - | - | - | - | - | - | 0.0 | 0.0 | 0.0 |
| Domestic exports | 2,784 | 1,937 | 1,486 | 1,921 | 2,178 | 1,132 | 2,161 | 1,334 | 857 | 2,260 | 1,875 | 687 | 1,414 |
| Re-exports (***) | 2 | 63 | 1 | 0 | 128 | 240 | 112 | 2,368 | 3,015 | 3,119 | 2,863 | 2,841 | 3,218 |
| **TOTAL EXPORTS** | **2,786** | **2,000** | **1,487** | **1,921** | **2,306** | **1,372** | **2,273** | **3,702** | **3,873** | **5,380** | **4,738** | **3,529** | **4,633** |

Source: Central Bank of Samoa April 2015

Samoa was once renowned as a leading exporter of top quality cocoa beans in the Pacific. With the planned revival of this commodity, attempts will be made to assist this process and the export of cocoa by focusing on value adding using the cocoa fermentation process.

Cocoa fermentation is a practice that has been employed by many local cocoa farmers to improve the flavour of the cocoa beans. However, the mechanisms and practices used were never formally studied, documented and standardized locally. Studies conducted elsewhere have repeatedly proven

the significant contribution of the fermentation process on the development of the distinctive cocoa and chocolate flavours.

## 2.1 Farmer consultation

In planning and designing this study the biggest cocoa farmers from the two islands were consulted and involved. Mr Saena Penaia of Melze Plantation from Upolu and Mr. Kolone Vaai from Savaii were consulted regularly. On-site visits to both farms were carried out a meeting between the project team and the two farmers was held in Savaii (Figure 1) to finalize the local best practice fermentation method to be used for the study. It was also agreed that the study will be conducted on-site at SROS using cocoa beans of the Trinitario variety from the two islands (farms) for comparison and to determine reproducibility of results.

**Figure 1. Meeting with the participating farmers in Savaii**

# 3.0 Objectives

The objective of this comparative study is to scientifically compare the local 'best practice' process for fermentation employed by the Samoan cocoa producers, and a proven overseas fermentation method, and their effects on the quality of cocoa beans and resultant end products. The ultimate goal is to use an evidence-based approach to improve local fermentation practices to ensure the quality of cocoa beans.

The specific aims were to:

- Compare the local fermentation and drying methods with the overseas recommended methods;
- Evaluate the effects of both methods on cocoa beans and resultant end products; and,
- Recommend improvements on local methods if required.

# 4.0 Methodology

Cocoa fermentation involves any of the three methods listed below:

1. Heap Fermentation
2. Basket Fermentation
3. Box Fermentation

After consultation with the two participating farmers involved (Figure 1), the local method was finalized with details listed in the experimental design below. The first trial used cocoa pods from Melze Plantation in Upolu and pods for the second trial were sourced from the Vaai plantation in Savaii.

The proven overseas fermentation method was adapted from the study funded by AusAid entitled, "Cocoa Processing Methods for the Production of High Quality Cocoa in Vietnam", was used for comparison purposes.

## 4.1 Research design

Cocoa fermentation is carried out with the many variable factors such as batch size, pod maturity, storage and fermentation conditions all having a bearing on the results. In this study, the "methods" were compared rather than specific "conditions". Figure 2 shows a flow chart of the research design.

The original intent of the project was to include koko Samoa, cocoa powder and butter as products to be produced and evaluated. However, it was found that this comparison would be very difficult to evaluate given the high variability in koko Samoa processing (open fire, uncontrolled temperatures for roasting, etc.) as well as the non-suitability of the equipment on-site for oil pressing. It was then decided that the focus will be on producing the fermented dried beans for chocolate making. This involves a more standardized and controlled process which is ultimately the high value targeted market for the cocoa farmers.

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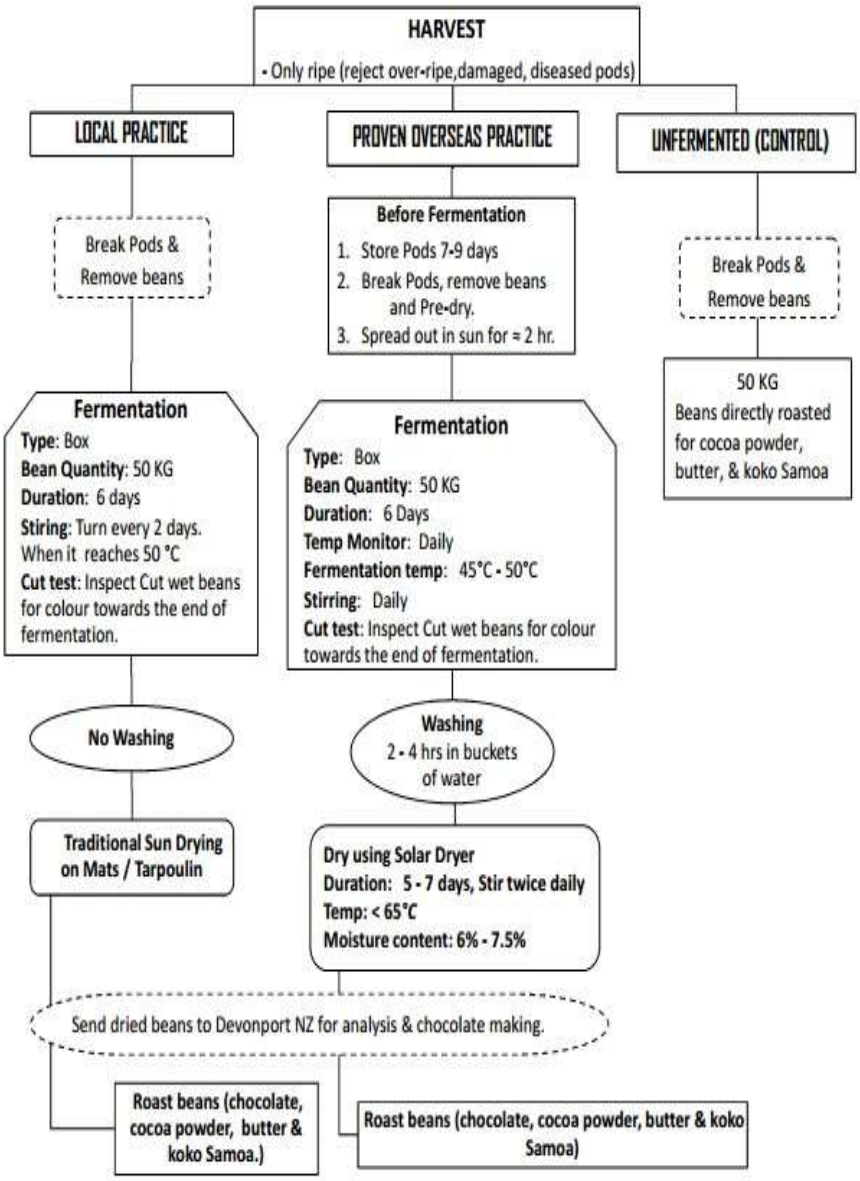



**Figure 2. Cocoa fermentation comparative study research design**

## 4.2 Trial 1 process

### 4.2.1 Cocoa pod selection

In May 2015, more than 1000 cocoa pods were harvested from the Melze Plantation with diseased or damaged cocoa pods removed from the selection. There are three cocoa varieties field-grown on this farm, Criollo (Figure 3), Forastero (Figure 4) and the most dominant variety, Trinitario (Figure 5) which was selected to be used for the study.

**Figure 3. Criollo cocoa pod**

**Figure 4. Forastero cocoa pod**

**Figure 5. Trinitario cocoa pod**

### 4.2.2 Fermentation

#### 4.2.2.1 Local method

The pods were opened on-site using a blunt knife so as not to damage the beans. 50 kg of wet beans were weighed and placed inside the fermentation box (lined with banana leaves), with dimensions of 49.5 cm (length) x 29 cm (width) x 35 cm (depth) and drainage holes in the bottom (Figure 6). Records of the weights for wet beans found that on average, 40 pods produced 5 kg of wet beans (Figures 7).

The beans were fermented for six days and turned every 2 days by hand with daily temperature recordings (Figure 8). A cut test was done at the end to observe the internal colour change and extent of fermentation for the beans.

**Figure 6. Fermentation box**

**Figure 7. Cutting and weighing on farm**

**Figure 8. Fermented beans**

#### 4.2.2.2 Overseas method

The fermentation method as detailed in Figure 2 was followed. The pods for the overseas method were harvested on the same day as those for the local method but were stored for seven days in a wooden box in the postharvest laboratory prior to opening (Figure 9). After seven days the pods were cut open, weighed and sun dried for 3 hours before 50kg of beans were placed for fermentation in another box with the same dimensions (Figure 10). The beans were turned daily with temperature readings recorded and a cut test was done at the end of six days to observe the internal colour change for extent of bean fermentation (Figure 11).

**Figure 9 Stored pods**

**Figure 10 Sun drying prior to fermentation**

**Figure 11 Cut test**

Figure 12 shows the temperature profile for the two methods over the six-day fermentation period. It should be noted however that the profiles are seven days apart with the overseas fermentation conducted later and thus do not represent the same days.

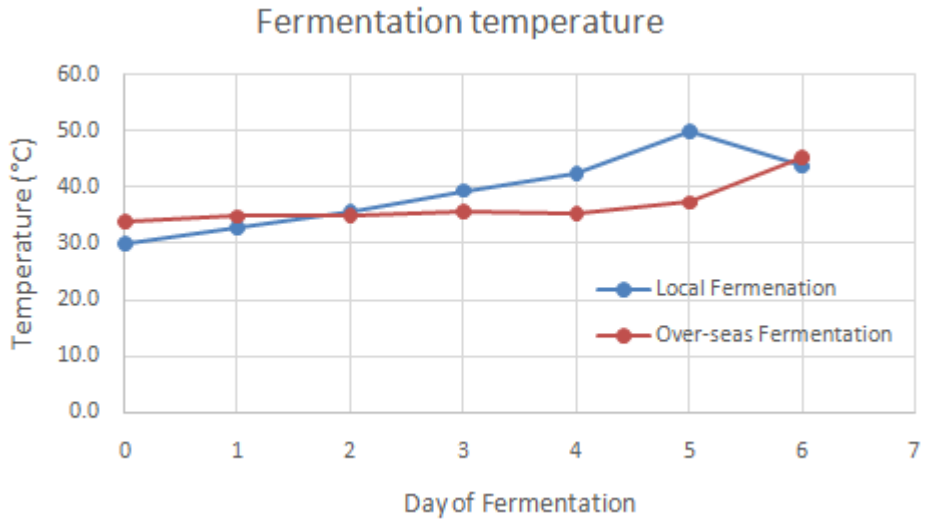



**Figure 12: Temperature recording for the two fermentation methods**

### 4.2.3 Drying

#### 4.2.3.1 Local method

At the end of six days, the fermented beans were placed on a tarpaulin and dried during sunny days (Figure 13). It took almost three weeks to fully dry the beans because of the frequent rain during the assessment period. Farmers usually determine proper dried beans by breaking them apart with their fingers.

This method was used to determine the drying period, and the results indicated the beans had on average 2.1% moisture content.

**Figure 13. Sun dried beans**

#### 4.2.3.2 Overseas method

After fermentation the beans were washed and soaked in buckets of water for two hours (Figure 14). The washing process removed dirt and immature beans which tended to float. After washing the beans, they were then spread out evenly on the solar dryer (Figures 15 & 16). After only seven days of drying, the cocoa beans were very dry. The recommended moisture content for dried beans is 6-7% while the content observed from the drying process was 5.9%.

The temperature loggers showed that during the seven days from 9am to 5pm (sun hours), the average daily temperature was 44.7$^0$C with a maximum of 52.2$^0$C and a minimum of 36$^0$C.

**Figure14. Washed beans**

**Figure 15. Solar dryer**

**Figure 16. Solar drying**

### 4.2.4 Sorting

Once the beans were dried they were sorted to remove the flat and poor quality beans (Figure 17). From the sorted beans, 3kg from each method were packed and sent to Devonport Chocolates in New Zealand for evaluation and chocolate making.

**Figure 17. Bean sorting**

## 5.0 Bean analysis and chocolate making

SROS was fortunate to be introduced to Devonport Chocolates during the consultation stage of the project and who had agreed to come on board as the end user for the fermented dried beans. Their specific role was to conduct the following on the fermented beans:

- Conduct a physical evaluation of the beans as received;
- Perform the cut test;
- Make chocolate mass from the beans; and,
- Produce chocolate tablets consisting of 68% cocoa and 32% sugar only.

Table 2 below details the results for the evaluation carried out on the beans they had received. It shows the beans were of very good quality with nil defects and 95% usable from both methods.

**Table 2. Dried and fermented beans evaluation results**

| Sample | Local method (Sample A) | Overseas method (Sample B) |
|---|---|---|
| **Visual inspection** | | |
| Insect damaged | Nil | Nil |
| Mouldy | Nil | Nil |
| Cracked shell | Minimal | Minimal |
| Bean size | 20-25mm | 18-22mm |
| Bean shape | Good | Good |
| Usable beans | 95% | 95% |
| **Cut test** | | |
| Less than well fermented | 16% | 16% |
| **Roast** | | |
| Moisture loss | 3.55% | 2.95% |
| **Window** | | |
| Shell loss | 9.28% | 5.87% |

The dried bean samples from both methods were also analysed for nutritional content (macronutrient) and is detailed in Table 3 below. For the local method involving direct sun drying, the cocoa beans were dried for so long due to inconsistently poor weather at the time resulting in very low moisture content. The ideal moisture level is around 6% to ensure longer keeping quality and drying below this level is also not economical as it greatly reduces product weight.

**Table 3. Nutritional content for Uplou sourced dried beans from the two fermentation methods**

| Tests | Units | Sample reference | | Method |
|---|---|---|---|---|
| | | Local method (direct sun dried) | Overseas method (solar dried) | |
| Protein | g/100g | 12.5 | 13.9 | AOAC 928.08 |
| Fat | g/100g | 42.5 | 46.6 | AOAC Ba3-38 |
| Moisture | g/100g | 2.1 | 5.9 | AOAC 925.40 |
| Ash | g/100g | 3.4 | 3.4 | AOAC 972.15 |
| Carbohydrates | g/100g | 39.6 | 33.2 | Calculation (by difference) |
| Energy | KJ/100g | 2,456 | 2,415 | Calculation |

The impact of drying on the moisture content directly affects the values for other macronutrients particularly carbohydrates as it is a calculated value. There appears to be slightly higher values for fat and protein content for the beans from the overseas fermentation method though not by much.

## 5.1 Chocolate tablets

The chocolate tablets were personally delivered by Mr Terry Everitt (Owner of Devonport Chocolates) during a meeting with the SROS project team, Mr Penaia and Asuao Kirifi the PHAMA National Coordinator (Figure 18). The samples were used for the local sensory evaluation carried out by the SROS team.

**Figure 18. Meeting with project partners and tasting of chocolate samples**


**Figure 19. Chocolate tablets**

Figure 19 shows the tablets made from the two fermentation methods and they were 68% cocoa with 32% sugar and no additives.

# 6.0 Sensory work and results for Trial 1

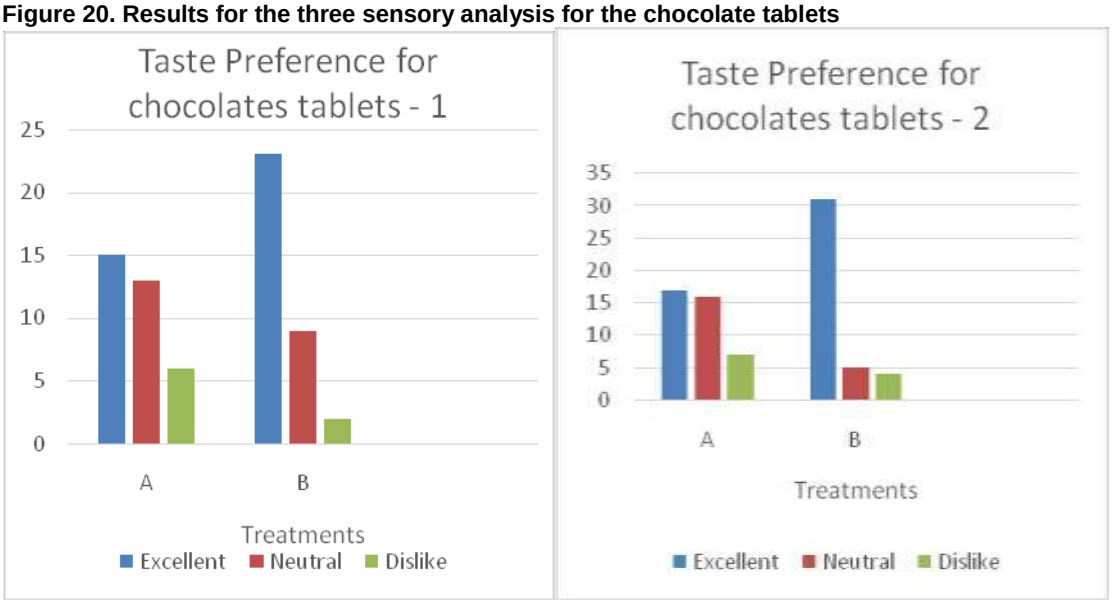
Three sensory exercises were conducted on separate but consecutive weeks using internal staff, visitors to SROS as well as members of the national MAWG. The panellists on all occasions were presented with two pieces of chocolate labelled A and B, and asked to rate them and indicate their preference in terms of taste.

**Table 4. Panelist form for chocolate evaluation**

| | RATING | TASTE |
|---|---|---|
| 5 | Excellent product | |
| 4 | Good product | |
| 3 | Neither like nor dislike | |
| 2 | Dislike | |
| 1 | Totally unacceptable | |

The results are detailed in Figure 20 with a re-grouping of good and excellent together, neither like or dislike as neutral and dislike and totally unacceptable as dislike.

**Figure 20. Results for the three sensory analysis for the chocolate tablets**




The graphs clearly indicate a preference for chocolate B made from cocoa beans fermented using the overseas method. The statistical analysis of results (Table 4) confirm that there is a significant difference between the two samples for all three sensory analysis conducted.

**Table 5. Statistical analysis of sensory results for chocolate tablets**

| | Chocolate tablet | |
|---|---|---|
| **Sensory** | **a** | **b** |
| 1 | 3.2b* | 3.7a |
| 2 | 3.3b | 3.9a |
| 3 | 3.2b | 4.2a |

* means in the same row (within sensory) followed by different letter are different at p<0.05 using LSD

The major difference between the two samples as per comments from tasters was that sample A from the local method was a lot more astringent compared to sample B. The scores are based on the 1- 5 scale from the evaluation form (Table 3).

# 7.0 Trial 2 results using pods from Savaii

For trial 2, more than a 1000 ripened cocoa pods were harvested from various small cocoa farms on the far eastern side of Savaii but mostly from around Papa Sataua in early November 2015. The same process was followed as detailed in trial 1 whereby cocoa pods were divided in two lots with one undergoing the local fermentation method and the other the overseas method. After fermentation and drying, samples of each treatment were packed and again sent to Devonport Chocolates for making chocolate samples for the sensory evaluation.

From the fermentation and drying trials the following information was gathered and noted for average weight loss for the trials which was mostly attributed to moisture loss.

**Table 6. Average bean weight loss for two, 50kg box trials after fermentation and drying**

| | Weights (kg) | Weight loss (%) |
|---|---|---|
| Total bean weight before fermentation | 52 | |
| Weight after six days fermentation | 43 | 17.3 |
| Weight after drying | 21 | 59.6 |

The average weight loss for cocoa beans from the two trials after drying was around 60% and this can change depending on the duration of drying at the prevailing weather conditions. The nutritional content of beans from both trials are listed in Table 7.

**Table 7. Nutritional content for Savaii-sourced dried beans from the two fermentation methods**

| Tests | Units | Sample reference | | Method |
|---|---|---|---|---|
| | | Local method (direct sun dried) | Overseas method (solar dried) | |
| **Fat** | g/100g | **35** | **37.4** | **AOCS Ba3-38** |
| **Protein** | g/100g | **13.7** | **11.4** | **AOAC 928.08** |
| **Moisture** | g/100g | **6.2** | **5.5** | **AOAC 925.40** |
| **Ash** | g/100g | **4.0** | **3.2** | **AOAC 972.15** |
| **Carbohydrates** | g/100g | **41.1** | **42.7** | **Calculation (by difference)** |

The macronutrient content of the above beans from Savaii differs from those sourced from Upolu (Table 3) particularly the fat and carbohydrate content. This difference may be attributed to different growing conditions (agronomic between the two islands) or may even be a seasonal effect with the two trials (beans from Upolu and Savaii) conducted at different times of the year (dry and wet). This

however can be a subject for another study. In terms of fermentation method and impacts on nutritional content of the beans, there does not appear to be any difference.

The chocolate samples were received in March 2016 and upon inspection we found chocolate samples A and B to contain different amounts of cocoa. Sample A (local method) contained 80% cocoa (20% sugar) while sample B had 62% cocoa (38% sugar). This was an error on Devonport‟s side and unfortunately could not be rectified as all the dried cocoa beans from the trials were used up. The results for the one sensory evaluation conducted are detailed in Figure 21 below.

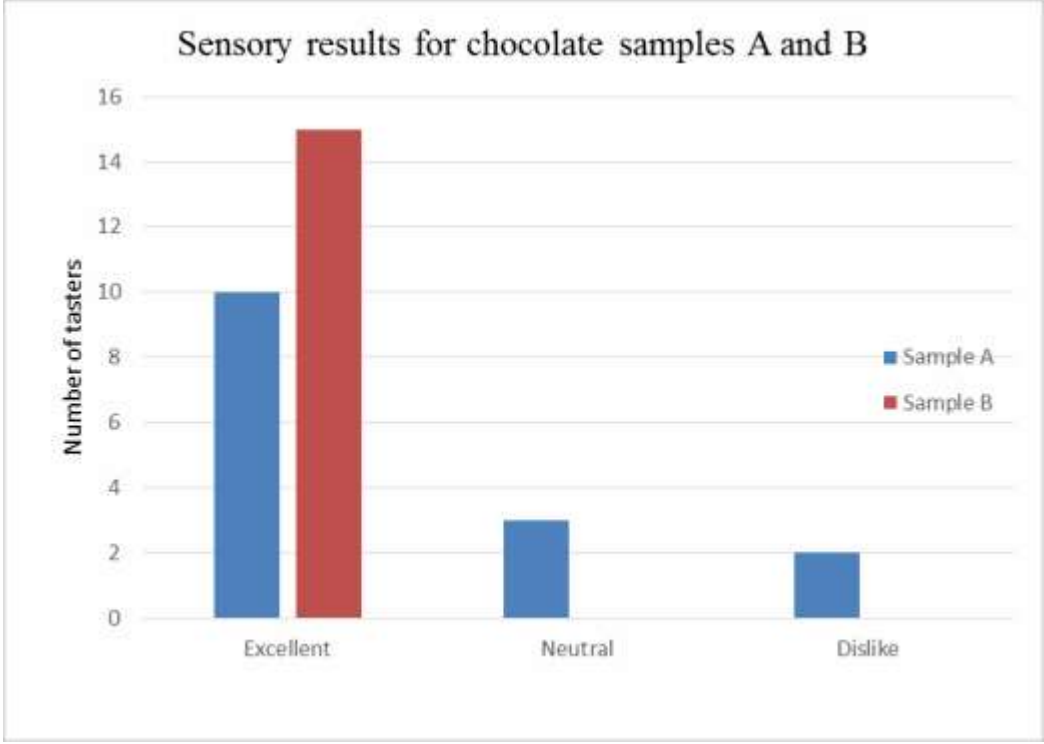



**Figure 21. Results for the sensory evaluation of chocolate tablets A and B**

Sample B as in trial one, was the most preferred with tasters having a clear preference for the chocolate made from cocoa beans fermented using the overseas method. This comparison however is not reliable due to the higher sugar content of sample B compared to sample A. It was for this reason only one sensory was conducted instead of three as was done for the first trial using cocoa sourced from Upolu.

# 8.0 Conclusion and recommendations

The effect of the fermentation practices used on the development of chocolate flavour for cocoa beans is well-known and has again been proven in this study. The local cocoa farmers believe that their traditional methods of fermentation produce the best quality beans particularly those intended for the export market, and this study has proven that it can be further improved with the incorporation of a few minor activities.

These activities include the following:

- Holding pods for at least five days before breaking
- Spreading beans in the sun for a few hours before fermentation
- Fermentation for at least five days with daily stirring
- Washing after fermentation and
- The use of a solar dryer if possible, for efficiency of the drying stage.

The chocolate samples produced from cocoa beans fermented with the recommended overseas method were preferred over the chocolate samples prepared from beans fermented using the local method. The use of the solar dryer was also proven to not only be very efficient in terms of drying time but was also very convenient during the rainy period.

Thus all things considered, the local farmers growing cocoa for the chocolate industry should be informed of the results of this study and be encouraged to incorporate the above changes to their fermentation methods to ensure the production of quality beans intended for the industry. The upcoming trials on farmer sites should follow and implement the recommended changes and send produce off to chocolatiers for use then provide feedback on the quality of the beans and resultant end product.

There appear to be differences in the macronutrient content of cocoa beans sourced from the two islands and this has an impact on the resultant quality of value added products. Future studies may focus on determining whether the differences are varietal, agronomical, seasonal or other. This should also then link to identification of the best cocoa varieties (or clones) for mass propagation to ensure a continuously thriving local cocoa industry.