On-farm site trials for proven cocoa fermentation and drying method.

Report prepared by;

The Scientific Research Organisation of Samoa (SROS)

for the

Pacific Horticultural and Agricultural Market Access Program

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Acknowledgement

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The SROS also acknowledges the support of its partners namely the cocoa farm owners of Melzi Plantation, Mulitalo Saena Penaia and Alo Kolone Vaai of Vaisala as well as Nia and Phil Belcher of Ola Pacifica Chocolates who to assisted the project through the evaluation of bean quality through chocolate making. We also acknowledge assistance provided through the Australian ACIAR Cocoa project for sensory analysis of the beans at the Department of Agriculture and Fisheries Laboratory in Queensland Australia.
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1. Introduction

Cocoa continues to be one of the Government of Samoa’s (GoS) priority crops and efforts to revivify the industry continues to attract donor funding support. The Australian and New Zealand governments in particular have new programmes assisting the cocoa industry in Samoa with a particular focus on the supply side of the value chain as the market has opened up again but supply is noted to be a major constraint.

The SROS conducted a comparative study funded by PHAMA in 2015, whereby the local fermentation and drying method was compared with a proven method from another Australian funded study in Vietnam. The results from this research found the overseas fermentation and drying method to produce better quality beans which were preferred for chocolate making.

This follow up work took the preferred method and implemented it on farmer site with the aim of conducting much larger trials using the selected farmers’ resources. This first farmer trial was conducted on Mulitalo Sena’s farm (Melzi Plantation) in Upolu and forms the first part of this report.

2. Background

Melzi Plantation (Upolu) and Kolone Vaai (Savaii) were the two selected farmers who supplied the cocoa for the initial research and were also the recipients of solar dryers funded by the PHAMA programme. The same farmers are used for this part of the work.

2.1 Quality checks

Two of SROS staff attended the Cocoa Quality Laboratory Training funded by PHAMA in the Solomon Island conducted by Commodity Export Marketing Authorities (CEMA) in February 2016. The training involved the learning of three major attributes in testing for bean quality and they are;

1. Standard physical Tests
   - % of foreign matters/ debris
   - Bean count
   - Cut -test
   - Shell content
   - Moisture content

2. Standard chemical Test
   - pH
   - Fat Content

3. Product development
   - Cocoa liquor preparation
   - Chocolate tasting (Sensory Evaluation)
The trials include testing for cocoa bean quality as outlined above and this was either carried out on-site or in the laboratory using equipment funded by the programme.

3. Objectives

The objectives of this second trial is to implement the proven overseas method on farmer site, and confirm the 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:

- Trial the overseas recommended methods specifically the *Fermentation method* in combination with the *Solar Dryer* out in the field;
- Confirm the quality of beans and resultant end products;
- Collect data to establish a database for cocoa quality attributes for formulation of a National Standard for exported fermented, dried cocoa beans.

It should be noted however that this trial was very late as funding was received in the first week of June the same week the farmer collected his very last harvest for the season. This impacted on the amount and quality of pods we had available for use and the size of our batch.
4. Methodology & Data collected

The fermentation method used was the proven overseas method from the research trial conducted by SROS in 2016, and originally adapted from the study funded by AusAid entitled, “Cocoa Processing Methods for the Production of High Quality Cocoa in Vietnam”.

4.1. Research Design

Figure 1 outlines the research methodology used for the Upolu trial and will also be used for the Savaii trial.

Figure 1: Flow Chart of the Research Design.
4.1a Harvesting and Storage of Pods

The last harvest for the season collected on the 7th June from Melzi Plantation was used for this trial. All three cocoa varieties are available on this farm, *Criollo*, *Forastero* with *Trinitario* being the most dominant one. The pods were screened for damage and infection and discarded, before the remaining pods were stored for 5 days in a wooden box (Figure 3) prior to opening.

The team visited the farm again the next day to check if another harvest was possible to increase the number of pods used but unfortunately there were no more fruits left.

A total of 1,126 pods were stored for 5 days to ensure they had fully ripened upon opening for fermentation. The pods were stored in a cool, dry place to reduce the possibility of fungal contamination when wet. This storage period also reduces the moisture level of opened pods which greatly assists with fermentation due to increased temperature. The pods should not be stored for too long otherwise the beans tend to germinate.

4.1b Breaking the pods

Pods were carefully broken with a blunt knife to avoid damaging the beans (Figure 4). Defected, diseased and damaged beans (Figure 5) were discarded and this resulted in the removal of 159 pods from the original 1,126. The beans were then spread out in the sun, on a plastic sheet for approximately two hours (Figure 6) which allowed further reduction in moisture loss. In the end the total bean weight used for fermentation was only 85 kg.

A lot of the pods were discarded due to germination and fungal growth.
4.1c Fermentation
The fermentation process can be conducted using heap, basket or box fermentation. Box fermentation (Figure 7) was used in this study and is the most common method used particularly for large scale operations. The 85 kg of wet beans was placed in the fermentation box with a temperature log tag and covered with banana leaves (Figure 8). The beans were turned daily (Figure 9) with temperature monitoring (Figure 10) and a cut test conducted at the end of 7 days to observe the internal colour change for extent of bean fermentation (Figure 11).

The daily turning of beans assists in raising the temperature during fermentation as it allows more moisture/water to be lost at the bottom and the incorporation of air resulting in more even fermentation. Graph 1 below shows the temperature profile obtained throughout the 7 days fermentation.
The fermentation temperature indicated the maximum temperature (50°C) was reached on the fifth day. For best fermentation results the optimum temperature range is between 45°C and 50°C and the closer to 50° the better the quality of dried cocoa.

4.1d Post fermentation
After fermentation the beans were washed and soaked in water buckets for 2 hours (Figure 12). The washing process removed dirt and immature beans which tended to float. The beans were also re-weighed (91kg) after washing, and the defected beans and foreign matter were weighed separately (392 g). The wet beans were then taken into the solar dryer (Figure 13) for drying.
4.1e Drying
The beans were spread out evenly inside the solar dryer (Figure 14) with the temperature log tag and digital temperature placed inside to monitor the temperature (Figure 15). A moisture analysis done on-site indicated the beans were fully dried on the 7th day (Figure 16). The recommended moisture content for dried beans is <7% and the moisture content observed from the drying process was 5.3% (Figure 17).

Figure 14: Spreading the beans

Figure 15: Temperature monitors

Figure 16: Moisture Meter

Figure 17: Dried Beans (32 kg)

The dried beans weighed around 32 kg after drying with a recovery rate of 37% from the 85 kg fresh weight and 35% recovery from the 91 kg weighed after soaking in water. This is within the expected recovery rate range of 30-40%.

The two temperature measuring devices placed in the solar dryer recorded the dryer performance. The temperature log automatically logged readings (Graph 2) while the temperature display device had manual readings (Graph 3) taken every afternoon when the cocoa was turned during the drying period.
The temperature logger indicated the average daily temperature to be 30.9°C with a maximum of 52.8°C and a minimum of 21.7°C. Some days had rain recorded which affected the average daily reading for the seven days and this is obvious in Graph 3 on days two and four.
Graph 3: Manual recorded temperature readings from the temperature display device

The plastic covering used for the solar dryer is not of the recommended quality (should be thicker) and is expected to be replaced soon when the order arrives from Australia. This is expected to better retain heat within the dryer and should result in higher temperatures and less drying time for the cocoa, but is yet to be confirmed.

4.1f Sorting
The dried beans collected was taken to the SROS laboratory and sorted to remove the flat and poor quality beans (Figure 18 & 19). From the sorted beans 15kg was kept by the SROS for its quality tests and 17kg was returned to the farmer. A 5kg sample (Figure 20) was packed and sent to Ola Pacifica in New Zealand for evaluation and chocolate making while the rest was used for bean quality analysis and trials for roasting time and temperature and for making cocoa liquor samples.

Figure 18: Sorting  Figure 19: Defected dried beans  Figure 20: 5kg sent to Ola Pacifica
This sorting process is crucial to ensure quality beans are selected for export or the chocolate industry while the sub-standard beans can be used for producing Samoan cocoa. The fact that more than 50% dried beans was considered sub-standard indicates the quality of pods we had to use for the trial as it was the very last harvest. A lot of germinated, diseased and light weight beans were found.
5. Quality Tests

As discussed earlier the physical and chemical tests are crucial for ensuring quality beans are selected. Some of the critical factors affecting the results of these two tests include the selection of pods, proper fermentation, dried to the proper moisture level, free from abnormal odours and mould contamination. The cut test in particular is an essential quality test which must always be performed for every batch of fermented beans.

The procedures for the analysis of physical attributes and pH of the beans was adopted from the ‘Laboratory Manual of Methods for Analysis of Dried Cocoa Beans’ of Commodity Export and Marketing Authority (CEMA) in the Solomon Islands.

5.1 Physical and chemical tests

The standards listed is also from the Solomon Islands and it should be noted these values are indicative only since physicochemical composition of crops can vary considerably depending on factors such as the climate (seasonal and annual variations), geographic and genetic factors, and the methods used for testing. Listed in Tables 1 and 2 below are the results for the physical and chemical tests with the exception of the cut test.

Table 1: Physical Analysis

<table>
<thead>
<tr>
<th>Test</th>
<th>Sample Reference</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreign Matter</td>
<td>&lt; 5%</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>Bean Count</td>
<td>88 beans / 100 g</td>
<td>80 -100 beans/100g</td>
</tr>
<tr>
<td>Shell Content</td>
<td>12.1%</td>
<td>15-17%</td>
</tr>
<tr>
<td>Moisture</td>
<td>5.7%</td>
<td>5.5- 7%</td>
</tr>
<tr>
<td>Dry Bean Recovery Rate</td>
<td>37%</td>
<td>30- 40%</td>
</tr>
</tbody>
</table>

Table 2: Chemical Analysis

<table>
<thead>
<tr>
<th>Test</th>
<th>Sample Reference</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fermented Solar Dried Cocoa Beans</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>50</td>
<td>55 -56%</td>
</tr>
<tr>
<td>pH</td>
<td>5.2</td>
<td>3.8 – 5.5</td>
</tr>
</tbody>
</table>

The results indicate the beans selected from the sorting process meet most of the test standards with the exception of the shell and fat contents which were both lower than the set limits. The shell content reflects the amount of waste consisting of the shells when the separated from the cotyledons and this low result is actually good, but may reflect beans used may have had less shell
intact. The fat however is lower than the required levels required for beans intended for the chocolate industry but this supports the results of the earlier research conducted which also indicated low fat levels in the local beans.

5.2 Cut Test
Cocoa beans are graded on the basis of the count of defective beans from the ‘cut test’. The cut test reveals the presence of certain defects which may cause off-flavours and indicates the degree of fermentation of the beans which has a bearing on the resultant flavour and quality. The International Standards Organisation cut test procedure states that for a complete determination of bean quality, beans shall be opened or cut lengthwise through the middle, so as to expose the maximum cut surface of cotyledons. Appendix 1 shows the chart used for assessing quality of beans using the cut test.

The cut test was conducted using a Guillotine knife cutter on 100 beans randomly selected from the batch. Figures 21 shows the first 50 beans in the guillotine just after cutting and Figure 22 shows all the 100 beans used for the cut test evaluation.

Figure 21: Guillotine
Figure 22: Cut Test after Solar Drying
Table 3: Cut test results

<table>
<thead>
<tr>
<th>Observations</th>
<th>Result</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Dark brown/ Blackish</td>
<td>13%</td>
<td>Over fermented</td>
</tr>
<tr>
<td>No. of Brown</td>
<td>74%</td>
<td>Fully Fermented</td>
</tr>
<tr>
<td>No. of Partly Brown/ purple</td>
<td>4%</td>
<td>Half/ Partially Fermented</td>
</tr>
<tr>
<td>No. of Purple</td>
<td>0%</td>
<td>Under Fermented</td>
</tr>
<tr>
<td>No. of Slaty</td>
<td>0%</td>
<td>Not Fermented</td>
</tr>
<tr>
<td>No. of Insect damage</td>
<td>0%</td>
<td>Defective Beans</td>
</tr>
<tr>
<td>No. of Mould</td>
<td>4%</td>
<td>Defective Beans</td>
</tr>
<tr>
<td>No. of Germinated beans</td>
<td>2%</td>
<td>Defective Beans</td>
</tr>
<tr>
<td>No. of Criollo</td>
<td>3%</td>
<td>Optional</td>
</tr>
</tbody>
</table>

The cut test indicates that 13% of the randomly selected beans were over fermented, 74% were fully fermented and 4% was partially fermented. There were mouldy (4%) and germinated beans (2%) found and this percentage again reflects on the importance of screening at the pod opening stage as well as after drying. The International Organisation for Standardisation (ISO 2451: 2017) for cocoa beans, Specifications and quality requirements, specify that good fermented beans should not contain more than 5% of slaty and not more than 5% of defective beans. The cut test results are good indicating the fermentation process to be successful in ensuring the beans produced are fully fermented and also highlights the importance of vigilant screening to remove defective beans as much as possible.

5.3 Cocoa liquor

The team also used the remaining beans to conduct trials for different roasting time and temperature profiles for the cocoa. The pH was also evaluated to determine if there was a time/temperature effect on the roasted beans.

Table 4: Roasting temperature, time and pH

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Roasting Time (min)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>150</td>
<td>30</td>
<td>5.19</td>
</tr>
<tr>
<td>155</td>
<td>30</td>
<td>5.15</td>
</tr>
<tr>
<td>160</td>
<td>30</td>
<td>5.1</td>
</tr>
<tr>
<td>165</td>
<td>25</td>
<td>5.17</td>
</tr>
<tr>
<td>170</td>
<td>20</td>
<td>5.15</td>
</tr>
</tbody>
</table>
Figure 18 below outlines the process used within the laboratory for making the cocoa liquor samples using each roasting profile and the samples are now stored in the freezer to be assessed together with any samples that will be produced by Ola Pacifica.

The samples are all 80% cocoa and 20% sugar with no other additives. These samples are representative of the future direction the cocoa industry in Samoa needs to consider of producing cocoa liquor bars, which are higher value compared to the beans alone.
6. Independent assessment of bean quality

For this first trial the quality evaluation by Ola Pacifica (Appendix 2), a buyer of Samoan beans, was essential to independently verify this fermentation and drying method produces quality beans. During a meeting between Mrs Nia Belcher and Kuinimeri when she delivered the cocoa mass bars (cocoa 80%: sugar 20%), she stated that the beans sent to her were very good and would recommend this fermentation process to any of the farmers she will work with in future.

The bars (Figure 24) upon tasting were delightfully very much chocolate (dark) bars with no additives. All the goodness of cocoa are included in this product and can be marketed as such.

![Cocoa mass samples](image)

*Figure 24: Cocoa mass samples made using Upolu trial beans by Ola Pacifica.*

In October 217, Dr Yan Diczbalis, Principal Horticulturist of the Department of Agriculture and Fisheries (DAF) of Queensland Australia and his colleagues visited SROS for a project scoping visit for the ACIAR Cocoa project. He was provided with 4 kg of cocoa beans from this trial for a scientific evaluation of the sensory attributes. The detailed report in Appendix 2 of PART 2 of this report contains the results for Saena’s cocoa beans and the following evaluation was extracted from it;

*5.2 Penaia.1*

A low intensity cocoa flavour. This sample was balanced in flavour with mild bitter and sweet notes. There were no defining characteristics that singled out this sample. This can be seen by its central location in figure 1.

*5.3 Penaia.2*

A high intensity bitter cocoa flavour with tartness characterised by a dark fruit/liquor attribute. This sample also exhibited mild spice and tropical notes.
Cocoa beans fermented using the above method was submitted by PHAMA for Saena to the International Cocoa Award, Cocoa of Excellence Programme held in Paris, September 2017 and the cocoa received an award as one of the best samples received.

7. Savaii trial
The second trial planned for Savaii is very important due to some issues encountered in this first trial for Upolu. These issues included;

- Ensuring the trial takes place during the main fruiting season and not at the end as this affects the quality of pods used,
- The solar dryer should have the recommended plastic covering in place to determine if there is a difference in heat retention and drying times,
- A larger batch should be fermented which is more representative of commercial farmer practices to realistically determine the quality of the fermentation practice,
- Include funding support for samples to be sent for quality assessment/feedback from buyers of the cocoa beans as this was not formally included in this first trial
Appendices

Appendix 1: Cut Test Chart
Appendix 2: Written feedback from Mrs Nia Belcher of Ola Pacifica a chocolate maker in New Zealand.

From: Nia Belcher <info@olapacifica.com>
Date: Wed, Oct 25, 2017 at 1:15 PM
Subject: comments on beans and chocolate Ola Pacifica
To: Kuinimeri Finau <kuinimeri.finau@srosmanagement.org.ws>

Talofa Kuinimeri

It was great to meet you in person and had a conversation on your project. Thank you for meeting us and taking the time to have a good dialogue.
The intention is great and an awesome initiative so i must congratulate you for taking on the challenge.

I must say that i was a bit reluctant when you first contacted me, i was very uncertain and a bit weary from the beginning as to why me and what was in it for me. Also since im not a lab technician or a quality evaluator and SROS is a government body with a lab and own objectives.
However, i treated this request the same as others' request. I occasionally get asked by a number of different growers throughout the Pacific to make chocolates using their beans. So after a few emails and phone call, my understanding is that you basically wanted me to confirm that the resulting beans from your documented process are good enough for any end products. The process you have documented could be rolled out as a recommended one for a potential market. So i proceeded to make chocolates using your beans as requested;
"...just following up on our cocoa work if you have managed to use them for any product or even evaluate their quality. We made some cocoa mass samples from the same batch but we're no experts to evaluate them if this is the quality you users require"

For the record, it must be noted that every chocolate maker and chocolatier makes own chocolate their own way, so mine would be different from other chocolate makers using same /similar beans.

So i made chocolate as a trial and initial test of what could be achieved from these beans.

I had not done a tasting profile or a scientific evaluation of quality as such.
This is purely to see what kind of chocolate could result, and the evaluation of chocolate quality then really depends on comparative personal taste.
My comments are:

When the beans first arrived, they look really good. On tasting, they were dry on the outside but the mid interior was slightly moist compared to other beans i have, they were good. I made 72% dark chocolate and was very happy with the outcome, in fact very pleasantly surprised. The chocolate had a good shine and tasted rather smooth.

I would like to say that i enjoyed making the chocolate and felt very privileged to be asked and Ola Pacifica being part of it. Making the chocolate and giving feedback is an important contribution and its a start. I am grateful and pleased that i made chocolate with it.

On taking them to Samoa, the climate being vastly different from New Zealand, i am keen to know how the chocolates stand. I do hope that the shine and taste remain the same when the people that requested these get round to tasting it.

I would be keen to work with this processing if any grower is willing to be a supplier of Ola Pacifica.

Thank you for the opportunity and look forward to hearing from you and receiving updates on further progress.

Faafetai tele

Nia Belcher
Kind regards

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Email: info@olapacifica.com
Website: www.olapacifica.com
https://www.facebook.com/olapacifica
Appendix 3 : Mulitalo Saena’s Certificate of Recognition from International Cocoa Awards
PART 2: KOLONE VAAI’S COCOA FARM

November 2017
On-farm site Trial 2 for proven cocoa fermentation and solar drying method.

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1. Research Design

The team planned and scheduled this work in consultation with Mr Alo Kolone Vaai. It was decided that to fully utilise the solar dryer capacity and to collect accurate data on its drying performance, the team needed to collect a lot of pods. It took two days to collect the necessary number, so it was decided two fermentation periods (days) will be studied and compared. The research design in Figure 1 below was thus used for this trial.

![Flow Chart of the Research Design of Trial 2 in Savaii](image-url)

Figure 1: Flow Chart of the Research Design of Trial 2 in Savaii.
2. Harvest

In the first week of November 2017 the project team travelled over to Savaii and started harvesting the cocoa pods. Harvesting took place on the 8th and 9th with 2,139 pods collected on the first day (Figure 2) and 3,653 pods on the second day (Figure 3) making a total of 5,792. Only ripe pods were picked and at this stage all pods were accepted for storage.

The first day’s collection was labelled Treatment 1 (fermented for 5 days) and the second harvest as Treatment 2 (fermented for 6 days).

![First Harvest, Treatment 1](image1)

![Second Harvest, Treatment 2](image2)

After each harvest, random pods were selected and weighed in lots of 50 in a sack (Figure 4) to get an average weight for the pods collected. 500 pods were weighed for Treatment 1 and 1000 for Treatment 2 as detailed in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>No collected pods</th>
<th>No of pods weighed</th>
<th>Average weight/50 pods in a sack</th>
<th>Average weight/pod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1</td>
<td>2,139</td>
<td>500</td>
<td>23 kg</td>
<td>460 g</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>3,653</td>
<td>1000</td>
<td>19 kg</td>
<td>384 g</td>
</tr>
</tbody>
</table>

The pods collected on the first day were notably bigger than those collected on the second day. This may be attributed to the part of the farm from which the pods were collected or may just be a coincidence.
3. Storage of Pods

After each harvest the pods were counted, weighed, placed in boxes and covered with palm leaves (Figure 5a and b) to ensure they don’t get wet as this promotes fungal growth. They were stored for five days in separate boxes before opening.

4. Breaking the Pods

The pods for each Treatment were opened on separate days after five days storage. The pods were firstly weighed (1000 randomly selected), then opened, before the beans were weighed. The selection of pods was done at this stage with germinated and infected ones being discarded.
Table 2: Data of pod weight and corresponding bean weight after opening of 1000 pods from each Treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of pods weighed</th>
<th>Weight of pods</th>
<th>Average weight pod</th>
<th>Number of rejected pods</th>
<th>Weight of beans from good pods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1</td>
<td>1000</td>
<td>401 kg</td>
<td>401 g</td>
<td>51</td>
<td>82 kg</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>1000</td>
<td>380 kg</td>
<td>380 g</td>
<td>83</td>
<td>77 kg</td>
</tr>
</tbody>
</table>

Table 2 data for the 1000 pods selected shows that Treatment 1 with the heavier pods had more beans and a slightly higher yield for wet beans. There is an obvious change in weight of pods after storage and this confirms the loss of moisture upon storage.

Twenty very small pods were randomly selected and weighed, gave a total weight of 5 kg giving an average weight of 250g/pod. The second collection had quite a few small pods included and this obviously affected the average weight for pods.

A total of 500 pods were rejected (Figure 6) at this stage leaving 5,292 to be fermented for both trials combined.

Figure 6: Cutting, selection of pods and eliminating defected beans.
Table 3: Total pod numbers, weights and yield of wet beans used for Treatments 1 and 2.

<table>
<thead>
<tr>
<th></th>
<th>Total number of pods</th>
<th>Number of rejected pods</th>
<th>Wet beans weight from good pods</th>
<th>Wet beans yield (%) from good pods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1</td>
<td>2,139</td>
<td>175</td>
<td>164</td>
<td>8</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>3,653</td>
<td>325</td>
<td>233.5</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>5792</td>
<td>500</td>
<td>397.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>

The beans after being weighed were spread out in the sun for two hours (Figure 8). This assists the fermentation process as more moisture is lost at this stage.

Figure 8: Sun drying for two hours before fermentation.

5. Bean Fermentation

Box fermentation was used for the trials. The inside of the boxes were covered with banana leaves with holes in the bottom allowing water to seep out. The selection of box was dependant on the size of the batch with a smaller box used for Treatment 1 (Figure 9) and a larger one for Treatment 2 (Figure 10).

The beans were thoroughly turned once, every day using either a shovel or hand to help incorporate air into the heap. Thorough turning ensures even fermentation and assists in raising the temperature to aid the process.
5.1 Fermentation Temperature
The data logger (Figure 10) shows the maximum temperature reached each day for the fermentation periods (5 and 6 days). For Treatment 1 fermentation, the maximum temperature reached was 47°C on day 5 and was not showing a downward trend when the process was stopped. For Treatment 2, the fermentation temperature reached a maximum of 48°C on Day 4, and was already showing a reduction by day 5. The best results are obtained for fermentation when the maximum temperature reached is between 45°C to 50°C and as a general rule, the closer the fermentation temperature to 50°C, the better the quality of the fermented cocoa.

The temperature data indicated the weight or size of the heap being fermented has an effect on the temperature and how quickly it reaches the desired range. Treatment 1 with the smaller heap size took a longer time (5 days) to reach a high temperature while it took only 4 days for Treatment 2 (larger heap size) to reach optimum fermentation temperature. The results also showed that to ensure optimum fermentation results, a minimum of 5 days should be recommended for fermentation time.
5.2 Post Fermentation

After fermentation, the beans were weighed again to determine the weight loss during the fermentation period.

Table 4: Weight change for beans after fermentation

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Initial weight before fermentation (kg)</th>
<th>Weight after fermentation (kg)</th>
<th>% weight loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1</td>
<td>164</td>
<td>138.5</td>
<td>15.5</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>233.5</td>
<td>205</td>
<td>12.2</td>
</tr>
</tbody>
</table>

Table 4 shows the percentage weight loss for cocoa beans after fermentation. Interestingly the beans for Treatment 1 (5 days) had a higher weight loss than those for Treatment 2 (6 days) and perhaps this has to do ability of the box to allow water to seep out from the bottom. The percentage weight loss for beans after fermentation appears to be between 12% and 16% with factors like the size of the batch and also box design having an impact on this percentage loss.
After weighing, the beans were then placed in large bins and soaked in water for an hour (Figure 11). This process washed out the floating foreign matter as well as defected beans (Figure 12).

Figure 11: Weighing of beans after fermentation, and soaking in water

Figure 12: Defected beans and foreign matter removed
6. **Cut Test during and after Fermentation**

The wet cut test during (Figure 13) and after fermentation (Figure 14) was to check the change in bean colour during the process. The colour should change from brown to darker brown at the end of fermentation. Beans which have fermented properly but are still wet, show a typical purple/brownish when open. Beans which are under-fermented will have a purple colour. Some beans may appear white due to the variety of cocoa and not necessarily be under-fermented. In all of these colour categories, beans will tend to darken in colour during drying as the majority of browning reactions will occur during this process.

![Figure 13: Wet Cut test at different stages of fermentation](image)

![Figure 14: Cut test after fermentation](image)

This test can be done as a check before the fermentation process is halted or stopped.

7. **Drying (Solar Dryer)**

Drying of cocoa is an important step in cocoa processing not only for preservative purposes but also for improvement of flavour and quality of cocoa products. The beans were spread out evenly inside the solar dryer on the shelves (Treatment 1 one side and Treatment 2 on another) made of plywood (Figure 15). Two devices for logging and displaying the temperature and relative humidity were placed inside for monitoring purposes (Figure 16).
Each Treatment on separate shelves on either side of the dryer, had a logger placed on the cocoa for recording temperature. The display temperature and relative humidity device was hung on the beams as shown in Figure 16.

The most critical quality parameter for dried beans, moisture level was continually tested on-site to check for dryness (Figure 17). The optimum moisture level is between 5.5 - 7%. Too high and fungal growth is possible and if too low, will not be economical as the beans will be too light when dried beans are sold directly.
7.1 Temperature profile inside the solar dryer

The two temperature and relative humidity measuring devices recorded the dryer operating conditions. The temperature log automatically recorded readings (Graph 2 & 3) while the temperature display device had manual readings taken (Graph 4 & 5) daily when the cocoa was turned during the drying period.

![Graph 2: Solar dryer temperature recordings for Treatment 1 beans](image)

The average temperature in the solar dryer during the drying time for Treatment 1 was 37.8°C with maximum temperature reached being 62.5°C (Graph 2). It took 5 days to fully dry the beans and upon testing random samples, the beans had an average of 5.3% moisture content.

![Graph 3: Solar dryer temperature recordings for Treatment 2 beans on opposite shelf](image)

The average temperature for Treatment 2 drying period was 35.6°C with maximum temperature reached of 63.8°C just before heavy rain fell starting from day 3 (Graph 3). The beans thus took
longer, 7 days to dry. The average moisture content was still slightly high, averaging around 7.2% when it was time for the team to leave for Upolu and so the remaining beans were left inside the solar dryer the whole day to ensure complete drying.

The team sorted and took 16kg for each Treatment to SROS office, and these beans from Treatment 2 were placed back into the research scale solar dryer (at SROS) for complete drying the next day.

Graph 4: Solar Dryer Temperature and Relative Humidity profile during drying

The data from Graph 4 shows the inverse relationship between temperature and relative humidity. The lower (or higher) the temperature the higher (or lower) the relative humidity. The lower temperature and consequently higher relative humidity was during the rainy periods and thus the cocoa beans for Treatment 2 took much longer to dry.

Graph 5: Temperature and Relative humidity recorded for the Solar Dryer and Ambient.
The data from Graph 5 just confirms that the solar dryer has a higher temperature and a lower relative humidity compared to the outside environment at all times. Thus the conditions created within the solar dryer promotes faster drying particularly during the wet season.

The performance of the solar dryer in terms of temperature (average and maximum) shows the solar dryer in Savaii reached much higher temperatures compared to that of Upolu. This is highly likely to be a direct result of the new more hardy plastic covering used for Kolone’s solar dryer which is the recommended dryer.

8. Sorting Process

The dried beans from Treatment 1 were taken to Kolone’s resort and sorted (Figure 18) to remove the flat and poor quality beans. Good beans were also selected for SROS laboratory analysis as well as for sending overseas for sensory evaluation. For Treatment 2, due to heavy rain which prolonged the drying period, there was not enough time to sort all the beans except only what was needed to take back to the laboratory. Table 5 details the weights and yield of dried beans from the wet beans fermented and pods used.

Table 5: Weights and yield of dried cocoa beans for the two Treatments

<table>
<thead>
<tr>
<th></th>
<th>Total number of good pods used</th>
<th>Total bean fresh weight</th>
<th>Bean total weight after drying (kg)</th>
<th>Weight of defected/low grade beans (kg)</th>
<th>Weight good beans (kg)</th>
<th>% yield dry cocoa (dry beans/wet beans)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1</td>
<td>1964</td>
<td>164</td>
<td>59.5</td>
<td>6.5</td>
<td>52.5</td>
<td>36</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>3328</td>
<td>233.5</td>
<td>96.5</td>
<td>Not sorted</td>
<td>41</td>
<td></td>
</tr>
</tbody>
</table>

The yield of dried beans from wet beans used range from 36 to 41% (unsorted) although, Treatment 2 actual yield is expected to be slightly lower as the beans were still left in the solar dryer for the whole day. The sorting process is crucial to ensuring quality beans are selected for the trade thus the quality of pods and consequently beans selected to be used from the start are very important.

For the two Treatments, the percentage yield of fermented, dried beans from the number of good pods used is around 3%.

Figure 18: Treatment 1 beans sorted, and defected beans removed at Kolone’s hotel
The sorting of Treatment 2 dried beans for beans to take to SROS laboratory was done inside the solar dryer so the remaining beans can still be dried (Figure 19). All the beans were weighed to get the yield of dry beans and the weight recorded is expected to drop slightly after further drying by Kolone’s workers to get it below 7% moisture.

![Figure 19: Treatment 2 dried beans sorted and weighed inside the solar dryer](image)

The beans from Treatment 2 taken to SROS were re-dried for 6 hours and 20 minutes in the research solar dryer at SROS compound with temperature readings detailed in Graph 6. The moisture level reduced to 5.7% by close of business as the weather was nice and sunny. The beans upon re-weighing had reduced in weight from 16.5kg to 14.5 kg.

![Graph 6: SROS solar dryer temperature profile used for re-drying Treatment 2 beans](image)
9. Quality Test

The physical and chemical tests are crucial for assuring the quality of beans. Some of the critical factors affecting the results of these two tests include the selection of pods, proper fermentation, drying to the proper moisture level, free from abnormal odours and mould contamination. The cut test in particular is an essential quality test which must always be performed for every batch of fermented beans.

The procedures for the analysis of physical attributes of the beans was adopted from the ‘Laboratory Manual of Methods for Analysis of Dried Cocoa Beans’ of Commodity Export and Marketing Authority (CEMA) in the Solomon Islands. The standards listed is also from the Solomon Islands and it should be noted these values are indicative only since physicochemical composition of crops can vary considerably depending on factors such as the climate (seasonal and annual variations), geographic and genetic factors, and the methods used for testing.

9.1 Physical and chemical Tests

Listed in Tables 5 and 6 below are the results for the physical and chemical tests with the exception of the cut test.

Table 5: Physical Analysis results

<table>
<thead>
<tr>
<th>Test</th>
<th>Sample Reference; Fermented Solar Dry Cocoa Bean</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment 1</td>
<td>Treatment 2</td>
</tr>
<tr>
<td>Waste Content</td>
<td>&lt; 3%</td>
<td>&lt; 3%</td>
</tr>
<tr>
<td>Bean Count</td>
<td>96 beans / 100 g</td>
<td>88 beans / 100 g</td>
</tr>
<tr>
<td>Shell Content</td>
<td>13 %</td>
<td>12.3 %</td>
</tr>
<tr>
<td>Moisture</td>
<td>4.9 %</td>
<td>5.7 %</td>
</tr>
<tr>
<td>Dry Bean Recovery Rate</td>
<td>36 %</td>
<td>&lt;40 %</td>
</tr>
</tbody>
</table>

Table 6: Chemical Analysis results

<table>
<thead>
<tr>
<th>Test</th>
<th>Sample Reference; Fermented Solar Dry Cocoa Bean</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment 1</td>
<td>Treatment 2</td>
</tr>
<tr>
<td>Fat</td>
<td>52.5%</td>
<td>47.4%</td>
</tr>
<tr>
<td>pH</td>
<td>4.8</td>
<td>5.1</td>
</tr>
</tbody>
</table>

The results indicate the beans selected from the sorting process meet most of the indicative test standards with the exception of fat content for Treatment 2 which was lower. This low level for fat was also found for the Upolu trial beans (50%) in Part 1 of the report which indicates a drafted cocoa standards for Samoa should consider a lower range for fat.
9.1.1 Cut Test

Cocoa beans are graded on the basis of the count of defective beans from the ‘cut test’. The cut test reveals the presence of certain defects which may cause off-flavours and indicates the degree of fermentation for the beans which has a bearing on the resultant flavour and quality. Appendix 1 shows the chart used for assessing quality of beans using the cut test. The cut test was conducted using a Guillotine knife cutter on 100 beans randomly selected from the Treatments and was conducted in Savaii after drying.

Figure 20a: 50 beans in the guillotine
Figure 20b: 100 cut beans

<table>
<thead>
<tr>
<th>Observations</th>
<th>Result</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment 1</td>
<td>Treatment 2</td>
</tr>
<tr>
<td>No. Dark brown/ Blackish</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>No. of Brown</td>
<td>76</td>
<td>85</td>
</tr>
<tr>
<td>No. of Partly Brown/ Purple</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>No. of Purple</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>No. of Slaty</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No. of Insect damage</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No. of Mould</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No. of Germinated beans</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>No. of Criollo</td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>

The cut test results (Table 7) indicates a high percentage of beans from both Treatments were fully fermented with 76% from Treatment 1 and 85% from Treatment 2. Treatment 1 had a slightly higher
percentage for half/partially and under fermented beans. There was 0% for mould, insect damage and slaty beans for both Treatments, and a 2% germinated for Treatment 1 and 6% for Treatment 2. This low percentage reflects the importance of screening at the pod opening stage as well as after drying.

The higher percentage of fermented beans for Treatment 2 is attributed to the higher temperature reached during fermentation compared to Treatment 1. The size of the heap (Treatment 2 being larger) greatly assisted as well. Some Criollo beans were present in the selection which was very good. The International Organisation for Standardisation (ISO 2451: 2017) for cocoa beans, Specifications and quality requirements, specify that good fermented beans should not contain more than 5% of slaty and not more than 5% of defective beans. The germinated beans (defective beans) should have been removed at the pod opening stage or after drying, and the results indicate that although Treatment 2 had more fully fermented beans it contained a higher percentage of defective beans which affected the quality rating of this batch.
10. Bean Sensory Assessment

From the beans selected for SROS analysis, four (4)kg from each Treatment were sent to Ola Pasefika for their evaluation as done for Part 1 Upolu trial. Two (2)kg each from both treatments were also sent to the Department of Agriculture and Fisheries (DAF) laboratory in Queensland Australia for an independent scientific sensory evaluation of the same.

![Message from Ola Pasefika](attachment:chocolate%20second%20batch%20test%20v1.1.pdf)

Figure 21: Ola Pasefika feedback for cocoa beans

Ola Pasefika gave collective feedback for both samples A and B as detailed in Figure 20. The comparison she is making therein is for the first batch of cocoa (Upolu trial) and this second trial (Savaii) and Ms Nia noted a slight difference between the two samples but felt the resulting chocolate quality was the same. Belcher overall was very satisfied with the quality of chocolate she made from the beans from both trials in Upolu (trial 1) and Savaii (trial 2).
Attached in Appendices (Appendix 2) is the scientific evaluation of the cocoa beans samples sent to DAF, Australia. The specific samples for this second trial is labelled SROS 4 and 5 and described with the following attributes;

5.7 SROS.4

A medium-high cocoa flavour with complimentary bitter, astringency and dark fruit/liquor attributes. This sample also exhibited unpleasant characteristics including barnyard and hammy notes.

5.8 SROS.5

An intense cocoa flavour with strong bitter and mild sweetness and tartness. This sample also had a slight smokey/ashy characteristic with mild dark fruit/liquor notes.

The old wooden fermentation boxes or the timber used as shelf cover in the solar dryer on which the wet beans were laid for drying may have contributed to the other attributes like smokey/ashy, barnyard and hammy notes the DAF sensory panel are picking up, but is not certain.

The SROS team received chocolate samples from Ola Pasefika (Figure 22) were also had a strong cocoa flavour but no bitterness, the same as Nia’s feedback.
11. Conclusions and recommendations

The revival of the cocoa industry in Samoa involves the amalgamation of all value chain factors from supply, to postharvest to processing and marketing. This project has provided very useful information for the farmers and are summarised below;

- The average fresh weight for pods straight after harvest varies greatly and ranges from 384g (Treatment 2) to 460g (Treatment 1) with a slight loss in weight (~7%) after storage,
- Yield of wet beans from number of pods is around 8%,
- Beans weight loss after fermentation is around 14%,
- Yield of fermented, dried beans from wet beans is around 38% and expected to be slightly lower when beans are sorted,
- To ensure optimum results, beans should be fermented for at least 5 days and more,
- The percentage yield of fermented, dried beans from the number of good pods used is around 3.5%, and is dependent on the quality of pods,
- Sorting at the pod cutting stage, removal of floating beans during washing and sorting after drying all contribute to ensuring quality beans are produced and selected for trade,
- The physical and chemical tests should all be carried out to complement the cut test for cocoa beans intended for the chocolate industry to ensure quality,
- Feedback from the sensory analysis by chocolatiers (research phase and on farm site trials) have proven the fermentation and drying method studied at Vietnam greatly improves the quality of the cocoa beans intended for the chocolate industry,
- The quality of material (eg wood) in contact with the beans when fermented and/or dried can impart an effect on the resultant end-chocolate flavor,
- This design of solar dryers can reach temperatures above 63°C with an average of 35°C, and are a must have for big cocoa farms to cater for the rainy season.

With a lot of technical projects supporting the revival of the cocoa industry in Samoa, it is important the farmers are not only planting the right varieties but are also implementing best practices for drying and fermentation to ensure quality dried beans are produced.

In this regard, it is recommended to,

- Inform the various cocoa farmers of the findings from this study so they are encouraged to change their practices accordingly,
- Seek assistance from the various cocoa projects to provide fermentation boxes and build more solar dryers for the local farmers particularly those with large plantations,
- A National standard for dried fermented cocoa beans should be developed and used for local and overseas trading,
- Ensure farmers who will be supplying the Trade, Commerce and Manufacturing (TCM) cocoa value added project with SROS and WIBDI supply a consistent quality of fermented, dried beans to ensure a consistent quality cocoa mass product.

It is important to also start seeking markets for the cocoa mass product to ensure the efforts in building the supply side of cocoa, together with the fermentation and drying work is complemented with efforts to build the market for the resultant value added end products.
Appendices

Appendix 1: Cut Test Chart

CUT TEST CHART

- Slightly Over Fermented
- Well Fermented
- Well Fermented (Pale)
- Slaty and Unfermented
- Slaty Turning Violet
- Violet
- Violet Turning Brown
- Partly Purple and Partly Brown
- Mouldy
- Mouldy and Infested
Appendix 2: DAF, Australia Sensory evaluation report

Flash Profiling of Chocolate Tasters
Philippa Tyler – Department of Agriculture and Fisheries
Sensory and Consumer Scientist
June 2018
1. Background

The complex processing methods that cocoa beans undergo following harvesting alters both their physical and chemical properties, developing individual characteristic flavours and making the product more palatable.
Sensory profiling enables a group of trained sensory assessors to quantify the individual characteristics of a food, which can then be applied to many areas, from guided product development to quality assurance.

In this instance, flash profiling has been conducted on chocolate tasters. The cocoa beans chosen have been processed using different methods which have imparted their own impacts on the flavour profiles of the chocolate tasters.

2. Main objectives
   ➢ Generate flavour profiles of the chocolate tasters.
   ➢ Define the dominant characteristics of each sample within the sample set.

3. Methodology

3.1 Sample preparation

Chocolate tasters were prepared in the Product Development laboratories of the Health and Food Sciences Precinct, Brisbane by Sensory Scientist Philippa Tyler and Food Technologist Colin Leung. The following method was adhered to;

➢ The cocoa beans were roasted in an oven (Arianna oven, model XF135, UNOX S.r.l, 35010 Vigodarzere – Padova, Italy) at 130°C for 10 minutes. The beans were placed in a single layer on steel trays lined with parchment paper and turned half way through the roasting process.
➢ Once cooled, the beans were cracked using a Champion Juicer (No. 5806413, model G5-PG-710-PN, Lodi California 95240) and winnowed by hand, using a commercially available hairdryer (Scunci Blow Out 2000W hairdryer, Frenchs Forest, Australia).
➢ All nibs were placed into the Champion juicer, with the filter attachment, and processed into cocoa liquor.
➢ The cocoa liquor, chocolate refiner bowl and stone grinders were placed in the oven for 15 minutes at 40°C prior to processing. This heating step aids the conching process by relieving the initial stress placed on the chocolate refiners.
➢ The refiner (Premier chocolate refiner Model No.507, India) was assembled and turned on whilst cocoa liquor was slowly added to the bowl.
➢ Cocoa liquor and melted cocoa butter were added to the bowl simultaneously, followed by the powdered sugar and soy lecithin.
➢ Once all ingredients were added the refiner was then left to run overnight for a total of 18 hours.
➢ After 18 hours of refining the chocolate was tempered; all chocolate was removed from the refiner and placed into a metal bowl. No additional heating to the recommended 45°C was required as the temperature of the chocolate when removed from the refiner was 50°C +/- 2°C. The chocolate was stirred using a spatula and cooled until a uniform 27°C was reached. At this point the bowl of chocolate was placed over a pan of simmering water in order to raise the temperature back up to a uniform 31°C at which point it was poured into plastic moulds, covered with cling film and placed under controlled conditions (18°C, 40% RH) for 4 hours until set.
When set, the chocolate tasters were removed from their moulds and placed into foil bags, which were sealed and placed back under controlled conditions (18°C, 40% RH) until they were required for sensory evaluation.

3.2 Sensory evaluation

A panel of experienced sensory assessors (n=11, aged between 28-64 years, 2 men and 9 women), took part in the study, led by panel leader Philippa Tyler. Nine samples of cocoa bean (table 1) were made into chocolate tasters and evaluated for their flavour attributes (table 2).

The flash profiling methodology was conducted. Flash profiling (FP) is a rapid descriptive method based on the quantitative evaluation of products using sensory attributes. It takes a snapshot picture of a product set as it is perceived by human subjects with emphasis on the relative sensory positioning of the products being evaluated. The method combines free choice of attributes and a comparative evaluation (using ranks) of the samples for each chosen attribute. The whole product set is evaluated at the same time.

Table 1 Sample details

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Details</th>
<th>Chocolate taster recipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mauala</td>
<td>2kg box ferment. Sun dried.</td>
<td>65.1% nibs, 3% butter, 31.55% sugar, 0.35% soy lecithin (1325g, 61g, 642g, 7g)</td>
</tr>
<tr>
<td>Penaia 1</td>
<td>Box ferment. Dried following Neil Holywood (Vietnam) protocol.</td>
<td>65.1% nibs, 3% butter, 31.55% sugar, 0.35% soy lecithin (1362g, 63g, 660g, 7g)</td>
</tr>
<tr>
<td>Penaia 2</td>
<td>Box ferment. Sun Dried.</td>
<td>65.1% nibs, 3% butter, 31.55% sugar, 0.35% soy lecithin (1115g, 53g, 559g, 6g)</td>
</tr>
<tr>
<td>SROS 1</td>
<td>10kg box ferment control.</td>
<td>65.1% nibs, 3% butter, 31.55% sugar, 0.35% soy lecithin (1340g, 62g, 638g, 6g)</td>
</tr>
<tr>
<td>SROS 2</td>
<td>5kg box ferment control.</td>
<td>65.1% nibs, 3% butter, 31.55% sugar, 0.35% soy lecithin (700g, 32g, 337g, 4g)</td>
</tr>
<tr>
<td>SROS 3</td>
<td>5kg box ferment treatment.</td>
<td>65.1% nibs, 3% butter, 31.55% sugar, 0.35% soy lecithin (480g, 22g, 232g, 2g)</td>
</tr>
<tr>
<td>SROS 4</td>
<td>164kg box ferment for 5 days, turning daily.</td>
<td>65.1% nibs, 3% butter, 31.55% sugar, 0.35% soy lecithin (1149g, 53g, 552g, 6g)</td>
</tr>
<tr>
<td>SROS 5</td>
<td>233.5kg box ferment for 5 days, turning daily.</td>
<td>65.1% nibs, 3% butter, 31.55% sugar, 0.35% soy lecithin (1058g, 44g, 465g, 5g)</td>
</tr>
<tr>
<td>Control</td>
<td>Lindt Chocolate 70% commercial sample</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Table 2 Sensory attributes
Training; the sensory panel undertook 2 two-hour training sessions led by Philippa Tyler. Throughout the training period assessors were exposed to each of the samples at several opportunities. Panel discussions were held to ensure the assessors were in agreement on the terms and descriptions used.

Formal evaluation; formal evaluations were held under controlled conditions in the isolated sensory booths at the Health and Food Sciences Precinct, Coopers Plains. Assessors carried out two formal evaluations of the nine products. Each assessor evaluated all nine products in each of the two different sessions. A Latin square design was used for each session that ensured each assessor evaluated the products in random order within the session and in different orders between sessions. Palate cleansers of water crackers, still and sparkling water were provided.

<table>
<thead>
<tr>
<th>Descriptors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flavour</td>
<td></td>
</tr>
<tr>
<td>Cocoa</td>
<td>Rich cocoa powder</td>
</tr>
<tr>
<td>Astringent</td>
<td>Mouth drying/puckering</td>
</tr>
<tr>
<td>Bitter</td>
<td>Burnt toast</td>
</tr>
<tr>
<td>Dark fruit/Liquor</td>
<td>Prune/date/sweet alcohol/brandy/rum/cherry liquor</td>
</tr>
<tr>
<td>Berry</td>
<td>Raspberry/strawberry</td>
</tr>
<tr>
<td>Tropical</td>
<td>Passionfruit/sour citrus/paw paw/banana skin/orange/pineapple</td>
</tr>
<tr>
<td>Spice</td>
<td>Cinnamon/cumin/star anise/peppery/chilli</td>
</tr>
<tr>
<td>Floral</td>
<td>Orange blossom/rose/jasmine/wattle</td>
</tr>
<tr>
<td>Nutty</td>
<td>Nuttiness of nut meat/nut skin</td>
</tr>
<tr>
<td>Savoury</td>
<td>Meaty/MSG</td>
</tr>
<tr>
<td>Resinous</td>
<td>Pine/dark or light tree resin/menthol</td>
</tr>
<tr>
<td>Woody</td>
<td>Dried wood</td>
</tr>
<tr>
<td>Leathery</td>
<td>Horse saddles/leather shop</td>
</tr>
<tr>
<td>Earthy</td>
<td>Dirt like/dusty</td>
</tr>
<tr>
<td>Barnyard</td>
<td>Dry grass with animal excrement/sweat</td>
</tr>
<tr>
<td>Tobacco</td>
<td>Pipe tobacco</td>
</tr>
<tr>
<td>Smokey/Ashy</td>
<td>Burning of wood</td>
</tr>
<tr>
<td>Hammy</td>
<td>Carved meats/ham/prosciutto/beef jerky</td>
</tr>
</tbody>
</table>
Data analysis; the flash profiling data consisted of the ranks given by each panellist to all samples from the product set independently for each attribute. The data analysis was performed using Generalised Procrustes Analysis (GPA) method (Dryden and Mardia, 2016; Dijksterhuis and Punter, 1990) in the Sensory module of the XLSTAT (Addinsoft, Paris, France, 2017). GPA uses an iterative method that aims at minimising the total variability across all configurations (called total sum of squares) to form a centroid configuration that gives a group consensus view of how the panellists perceive the products. Once the group consensus is found, it provides different residuals to assess the variability of each individual configuration and their difference from the group consensus, deviations of the products from the group consensus, and performs Principal Component Analysis (PCA). The resulting biplot from PCA provides the description of the products based on the group consensus.

In the instances where an attribute was not present in >4 of the samples the data was not included in the PCA, as GPA and subsequently PCA require ranks to be given to each sample. These characteristic attributes however still form an integral component of the individual sample profiles, and have therefore been highlighted in the sensory profiles detailed in sections 4.2 of this report.

4. Results

4.1 Principle Component Analysis (PCA) Bi-Plots of aroma and flavour
A bi-plot is an enhanced scatterplot that uses both points and vectors to represent structure. The axes of a bi-plot are a pair of principal components (a linear representation of the correlated observations) and are called F1 and F2 above. A bi-plot uses points to represent the scores of the observations on the principal components, and it uses vectors (lines with both angle and direction) to represent the coefficients of the variables on the principal components. In this instance the points are chocolate tasters and the vectors are sensory attributes. The percentage given in brackets indicates the amount of variation explained by each principle component.
5. Sensory profiles

5.1 Mauala

A medium-high intensity bitter cocoa flavour with woody earthy characteristics. This sample was pleasantly sweet with no tart or astringent attributes present.

5.2 Penaia.1

A low intensity cocoa flavour. This sample was balanced in flavour with mild bitter and sweet notes. There were no defining characteristics that singled out this sample. This can be seen by its central location in figure 1.

5.3 Penaia.2

A high intensity bitter cocoa flavour with tartness characterised by a dark fruit/liquor attribute. This sample also exhibited mild spice and tropical notes.

5.4 SROS.1

A low intensity cocoa flavour characterised by strong sweetness and slight malt/biscuit notes.

5.5 SROS.2

As above, SROS.1 and SROS.2 exhibited very similar flavour profiles. A low intensity cocoa flavour characterised by strong sweetness and slight malt/biscuit notes.

5.6 SROS.3

Low-medium cocoa intensity with slight tartness. This sample was characterised by its berry and tropical attributes.

5.7 SROS.4

A medium-high cocoa flavour with complimentary bitter, astringency and dark fruit/liquor attributes. This sample also exhibited unpleasant characteristics including barnyard and hammy notes.

5.8 SROS.5

An intense cocoa flavour with strong bitter and mild sweetness and tartness. This sample also had a slight smoky/ashy characteristic with mild dark fruit/liquor notes.

5.9 Control

An intense cocoa sample with a characterising strong coconut attribute. This sample also exhibited slight berry and mild dark fruit/liquor and spice notes.