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# PP1800: National Papaya Breeding and Evaluation Program. Market preferred papaya flavours and other sensory types

## Report on sensory evaluation of 2022 season fruits

The Queensland Alliance for Agriculture and Food Innovation (QAAFI) is a research institute of The University of Queensland (UQ), supported by the Queensland Government

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# Project Objectives

The main objectives of this project were:

- To obtain sensory profiles of advanced papaya breeding lines
- To compare the sensory properties of advanced papaya breeding lines with commercial papaya varietals

# Material and Methods

## Approach

A trained panel study (descriptive profiling) was conducted for the papaya varieties in August 2022:

## Sample preparation

Papaya samples were delivered by the client the week prior to sensory training and/or formal evaluation with the trained panel. Depending on fruit ripeness level, the papaya samples were stored at either 12°C (ripe), 15°C (nearly ripe), or at room temperature (22°C) (not ripe at all). One delivery of fruit, at each harvest time, was used for the entire duration of each separate sensory trial.

Papaya samples were prepared on the morning of each tasting session by cutting whole fruit in half, removing seeds and skin with a knife, and cutting the flesh into cubes (~1.5-2.0 $cm^3$). Cubes of fruit (~15-20 g) were dispensed into porcelain cups (50 ml size), labelled with a 3-digit code, covered with an aluminium foil and stored at room temperature until use (**Figure 1**). The photos of whole papayas and halved papayas are in Appendix 1 and 2. A detailed method of cutting papaya samples can be seen in Appendix 3. Individual fruits were used for each replicate in formal evaluations. Where fruits were particularly small, two fruits were used as a composite sample for a single replicate. The papaya varieties used for the sensory evaluation are listed in **Table 2**.

*Figure 1: Photographs depicting preparation of papaya samples for formal evaluation*

*Table 2: List of papaya varieties assessed in sensory evaluation with trained panel*

| Sample # | Variety group | Commercial variety? | Papaya variety |
|---|---|---|---|
| 1 | F5 Yellow Breeding Line | No | PBL10 |
| 2 | F5 Yellow Breeding Line | No | PBL11 |
| 3 | F5 Yellow Breeding Line | No | PBL13 |
| 4 | F5 Yellow Breeding Line | No | PBL14 |
| 5 | F5 Yellow Breeding Line | No | PBL15 |
| 6 | F5 Yellow Breeding Line | No | PBL12 |
| 7 | Yellow | Yes | 1B |
| 8 | Red | Yes | RB1 |
| 9 | Red | Yes | Holland 5 |
| 10 | Red | Yes | Holland 6 |
| 11 | Red | Yes | Tainung |
| 12 | Red | Yes | Solo |

## Descriptive profiling

Ten trained sensory panellists (seven female and three male) participated in the study, aged between 21 and 59 years (with an average age of 41). These panellists were sourced from a pool of experienced trained assessors who had previously been screened for sensory acuity and were experienced in trials involving tropical fruit.

Conventional quantitative sensory descriptive analysis method was used to characterise the sensory properties of the twelve papaya samples with three repetitions. Four training, one practice and two formal assessment sessions were conducted over a period of two weeks.

The training involved familiarising the panellists with the samples; developing an assessment protocol, developing a concise vocabulary to describe the sensory properties of the samples; defining the sensory attributes; developing corresponding sensory reference standards and developing scales and anchors for rating the attributes. All samples were introduced to the panellists at least once during training. One practice session was held at the end of the training phase that mimicked a formal evaluation session, wherein panellists' discrimination performance and repeatability were assessed.

Formal evaluation sessions were conducted in two days, completing four replicates of all papaya samples. A balanced sample presentation was used within each replicate for all trials. In each session, panellists were asked to go through the definitions of the attributes and re-assess the sensory reference standards before assessing samples. The method developed for assessment is detailed as follows:

- *Lift lid to assess aroma*
- *Using a metal spoon to lift the fruit, assess whole fruit cubes (don't cut/damage the whole cube)*
- *Sample one full cube of fruit to assess texture*
- *Sample another full cube of fruit to assess flavour and aftertaste*
- *If required, sample the third full cube of fruit*

- *Rinse palate with water and rest for at least 30 seconds, before assessing next sample.*

The sensory properties rated included 7 aroma, 5 texture, 7 flavour and 4 aftertaste attributes. Other aroma and other flavour attributes were also included for panellists to rate and describe if any other sensory properties were perceived during the tasting. The sensory attributes, together with their definitions and composition of the sensory reference standards are detailed in **Table 3**. All attributes were rated on unstructured line scales (0-100), anchored from 'none' to 'high'. Within a 2-hour session, a maximum of 12 samples were presented with forced 30-second breaks between samples. Data were collected electronically using the software RedJade (RedJade Software Solutions, LLC, Tragon Corporation, California, USA, 2021).

*Table 3: Sensory attributes and definitions used in the sensory descriptive study*

| Attribute* | Definition | Reference Standard |
|---|---|---|
| ***Aroma*** | | |
| *overall aroma intensity* | The overall aroma intensity from none to high | n/a |
| *sweet fruit* | Aroma of fresh sweet fruit such as honeydew melon or mango | ~1x2 $cm^3$ cut honeydew melon piece w/o skin, 1ml orange juice (Golden Circle, no added sugar, Orange Juice, long life) |
| *musty- off note* | Aroma of ripe rock melon, over-ripe fruit, sulphurous, fermented | ~1x2 $cm^3$ cut rock melon piece w/ skin |
| *fishy* | Aroma of tune, fishy, or seaweed | ~0.5 $cm^3$ piece canned tuna (Aldi Ocean Rise Yellowfin tuna in Springwater) |
| *citrus* | Aroma of citrus peel or juice | 1 cm each string of rind from an orange, mandarin and lemon |
| *floral* | Floral notes (Jasmine flower) | ¼ drop of Jasmine flower essence (Aromaster Wine Kit bottle #24) |
| *green* | Green notes (cucumber, grassy) | n/a |
| *other* | Any other aroma (please describe) | n/a |
| ***Texture*** | | |
| *resistance* | Degree to which sample resists initial bite, firmness, could be crisp when high | n/a |
| *velvety* | Smoothness of sample during initial 2-3 bites (lack of particles/grit), silky smooth is high | n/a |
| *juiciness* | Degree to which liquid is released on mastication (first 2-3 bites) | n/a |
| *dissolving* | Degree to which sample dissolves/disintegrates in the mouth | n/a |
| *fibrous* | Presence of fibrous pieces, debris | n/a |
| ***Flavour*** | | |
| *flavour intensity* | The overall flavour intensity from none to high | n/a |
| *sweetness* | Sweet flavour associated with cooked sweet potato/carrot, sweet melon with caramel notes, confectionary | 25 g/L sucrose solution |
| *sourness* | Sour flavour | n/a |
| *bitterness* | Bitter flavour | 0.3 g/L caffeine solution |
| *musty* | Flavour of over-ripe rockmelon with skin, stale | As for aroma |
| *floral* | Floral notes (Jasmine flower) | As for aroma |
| *green* | Green flavour (cucumber, grassy) | n/a |

| Attribute* | Definition | Reference Standard |
|---|---|---|
| *other* | Any other flavour (please describe) | n/a |
| ***Aftertaste*** | | |
| *bitter* | Bitter aftertaste | As above in flavour |
| *sweet* | Sweet aftertaste | As above in flavour |
| *metallic* | Metallic aftertaste | n/a |
| *prickly* | Tingle or heat of pepperiness | n/a |

All attribute scales anchored none-high. All training sessions were conducted in a meeting room equipped with an electronic whiteboard. Practice and formal evaluation sessions were held in the purpose-build sensory evaluation laboratory facility at the Elkhorn Building, UQ Long Pocket Campus. The laboratory is equipped with 14 isolated sensory booths, iPads, temperature controlling (22°C) and LED light controlling (day-light equivalent lighting) (**Figure 2**).

## Data analysis

Data was exported from RedJade into Microsoft Excel for analysis. XLSTAT (2022.2.1, Paris, France) was used to analyse panellist performance, for product characterisation and data exploration and analysis.

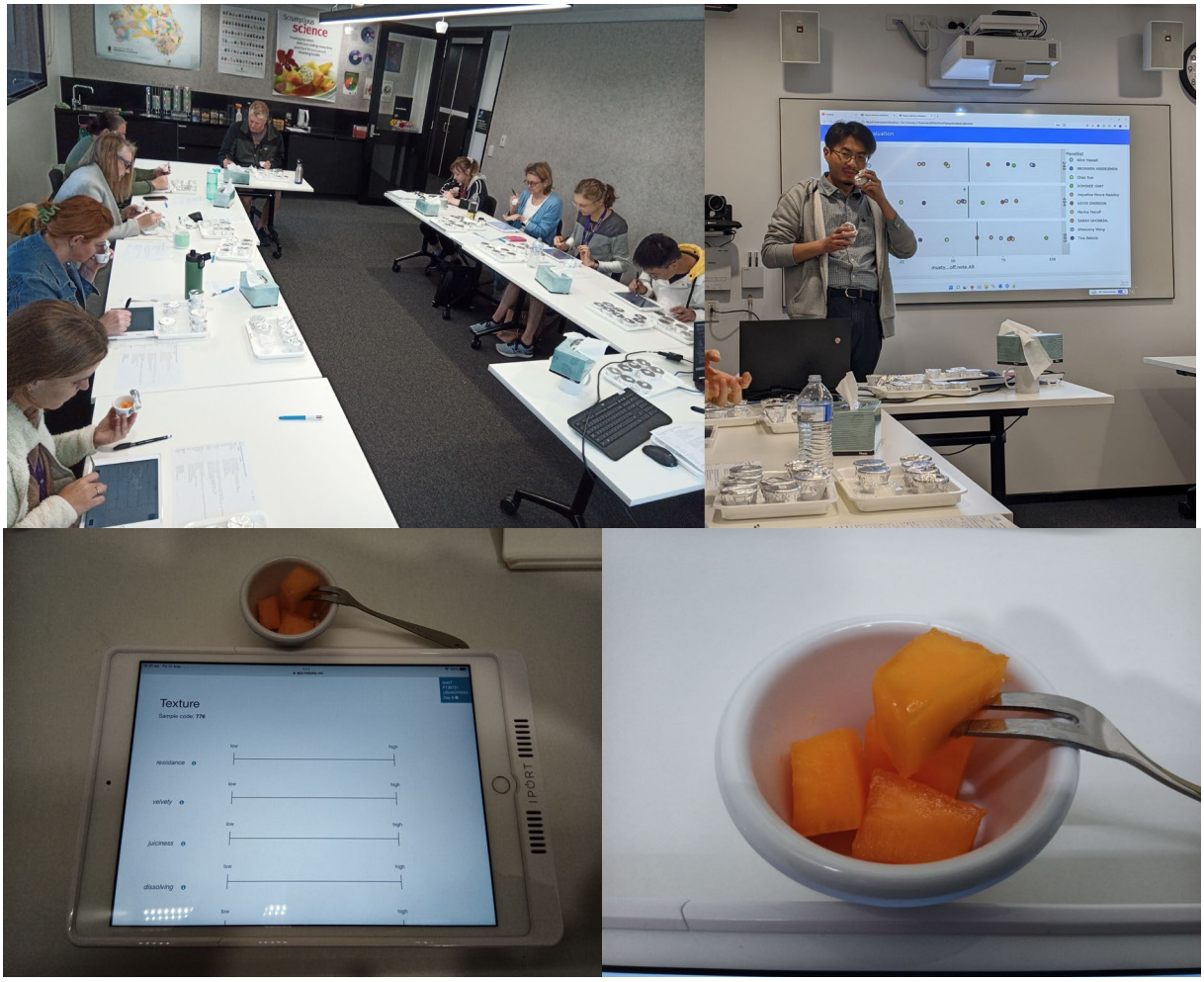
### Descriptive profiling

For all sensory attributes, descriptive statistics on the scores was calculated including minimum, maximum, mean, standard deviation, coefficient of variation (CV), and standard error of the mean (SEM).

For testing discrimination power and repeatability of the panellists, Analysis of Variance (ANOVA) was performed on the sensory scores provided by each panellist; the ANOVA model used for testing discrimination power was attribute = F(product) and that for repeatability was attribute = F(session). The panellist's agreement with the entire panel was calculated as attribute = F(panellist x product). A mixed model ANOVA, with product as the fixed effect and panellists, sessions and pair-wise interactions between product and panellist, panellist and session and session and product as random effects is conducted on the whole dataset for each attribute ($p < 0.05$). Those panellists who had less than 50% discrimination power of the panel's average were excluded prior to further statistical analyses.

The mean score of all the sensory attributes for each product was calculated and a Tukey HSD was conducted to evaluate whether the products were significantly different from each other based on the attributes ($p < 0.05$). Finally, a principal component analysis (PCA) was performed on the mean scores for all samples to visually observe sample differentiation. The sensory attributes without significant differences across products were not included in the PCA.

*Figure 2: Photographs of training and formal evaluation sessions*



# Results and Discussion

## Descriptive profiling

### Panel performance and quality of sensory data

To explore the sensory scores and determine panel performance, the mean, maximum, minimum, standard deviation standard error of the mean and coefficient of variation of each of the sensory attributes rated by the panel of 10 across the 12 papaya samples were calculated as shown in **Table 4**. The coefficient of variation for most attributes was greater than 50%, indicating that sufficient variability was observed among samples.

*Table 4: Summary of the descriptive analysis scores (n= 12 samples x 4 replicates x 9 panellists)*

| | Min | Max | Mean | SD | CV% | SEM |
|---|---|---|---|---|---|---|
| *aroma intensity AR* | 25 | 81 | 52 | 27 | 52% | 1.26 |
| *sweet fruit AR* | 23 | 63 | 46 | 28 | 60% | 1.30 |
| *musty - off note AR* | 26 | 63 | 41 | 30 | 72% | 1.39 |
| *fishy AR* | 9 | 50 | 24 | 29 | 123% | 1.36 |
| *citrus AR* | 5 | 56 | 23 | 28 | 121% | 1.33 |
| *floral AR* | 4 | 42 | 18 | 26 | 141% | 1.22 |
| *green AR* | 18 | 30 | 24 | 28 | 118% | 1.33 |
| *resistance TX* | 19 | 82 | 44 | 31 | 70% | 1.46 |
| *velvety TX* | 28 | 64 | 49 | 29 | 58% | 1.34 |
| *juiciness TX* | 29 | 73 | 53 | 28 | 52% | 1.29 |
| *dissolving TX* | 17 | 75 | 52 | 31 | 60% | 1.44 |
| *fibrous TX* | 35 | 68 | 47 | 30 | 63% | 1.39 |
| *flavour intensity FL* | 25 | 75 | 56 | 24 | 42% | 1.10 |
| *sweetness FL* | 16 | 70 | 50 | 28 | 55% | 1.29 |
| *sourness FL* | 11 | 40 | 21 | 26 | 125% | 1.22 |
| *bitterness FL* | 10 | 63 | 32 | 32 | 101% | 1.50 |
| *musty FL* | 24 | 59 | 41 | 27 | 65% | 1.26 |
| *floral FL* | 6 | 49 | 23 | 29 | 130% | 1.38 |
| *green FL* | 15 | 36 | 23 | 27 | 118% | 1.28 |
| *bitter AT* | 10 | 54 | 27 | 30 | 108% | 1.39 |
| *sweet AT* | 4 | 58 | 34 | 27 | 82% | 1.29 |
| *metallic AT* | 7 | 16 | 11 | 20 | 178% | 0.94 |
| *prickly AT* | 6 | 11 | 8 | 17 | 215% | 0.79 |

Suffixes: AR, aroma attributes; TX, texture attributes; FL, flavour attributes; AT, aftertaste attributes.

SD, Standard deviation; CV, Variation coefficient; SEM, Standard error of the mean.

Analysis of variance was conducted to evaluate the panel performance (**Table 5**). Discrimination power shows the number of attributes panellists were able to discriminate among samples, while repeatability indicates the number of attributes panellists were able to discriminate consistently throughout the four replicates. "No interaction" indicates the number of attributes that the current panellist agreed with the entire panel's opinion. Overall, most of the panellists performed well, being able to discriminate the majority of the attributes, with only panellist 8 being able to discriminate much fewer attributes than others. Hence, the data from panellist 8 was excluded from the further analyses of F-ratios, ANOVA and PCA. The majority of panellists were also able to rate the samples consistently across sessions with a nice consensus.

*Table 5: Summary of panellist performance, discrimination power and repeatability determined from an ANOVA model of the sensory data obtained for samples. (n=12 samples x 4 replicates x 9 panellists)*

| Panellist | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Discrimination | 12 | 16 | 8 | 12 | 17 | 11 | 16 | 4 | 16 | 13 |
| Repeatability | 23 | 23 | 23 | 11 | 21 | 18 | 24 | 18 | 20 | 25 |
| No interaction | 21 | 15 | 20 | 14 | 16 | 20 | 19 | 6 | 16 | 16 |
| Total | 56 | 54 | 51 | 37 | 54 | 49 | 59 | 28 | 52 | 54 |

The discrimination power denotes the total number of attributes for which there is a significant difference ($p < 0.05$) across all the samples; repeatability denotes the number of attributes for which there is no significant difference ($p < 0.05$) across the four replicates for the same product. "No interaction" denotes the number of attributes for which one panellist rated has no significant difference ($p < 0.05$) from the panel's consensus. The ideal value for Total is 75.

*Table 6: F-ratios and significance for effects of 12 samples, panellist and replicate (4 replicates x 9 panellists)*

| Sensory attribute | Sample | Panellist | Replicate |
|---|---|---|---|
| *aroma intensity AR* | 25 *** | 11 *** | 2 ns |
| *sweet fruit AR* | 19 *** | 15 *** | 3 ns |
| *musty - off note AR* | 8 *** | 20 *** | 4 ** |
| *fishy AR* | 15 *** | 6 *** | 1 ns |
| *citrus AR* | 31 *** | 17 *** | 1 ns |
| *floral AR* | 14 *** | 19 *** | 1 ns |
| *green AR* | 1 ns | 44 *** | 0 ns |
| *other aroma AR* | 1 ns | 2 * | 1 ns |
| *resistance TX* | 72 *** | 5 *** | 3 * |
| *velvety TX* | 10 *** | 5 *** | 2 ns |
| *juiciness TX* | 32 *** | 11 *** | 0 ns |
| *dissolving TX* | 56 *** | 5 *** | 3 * |

| Sensory attribute | Sample | Panellist | Replicate |
|---|---|---|---|
| *fibrous TX* | 6 *** | 26 *** | 2 ns |
| *flavour intensity FL* | 28 *** | 24 *** | 3 * |
| *sweetness FL* | 26 *** | 12 *** | 0 ns |
| *sourness FL* | 8 *** | 41 *** | 2 ns |
| *bitterness FL* | 17 *** | 20 *** | 2 ns |
| *musty FL* | 8 *** | 22 *** | 4 * |
| *floral FL* | 12 *** | 34 *** | 1 ns |
| *green FL* | 5 *** | 70 *** | 3 * |
| *other flavour FL* | 1 ns | 2 * | 1 ns |
| *bitter AT* | 13 *** | 18 *** | 4 ** |
| *sweet AT* | 16 *** | 13 *** | 1 ns |
| *metallic AT* | 2 * | 43 *** | 1 ns |
| *prickly AT* | 1 ns | 100 *** | 2 ns |

Significant F-ratios are indicated by * ($p < 0.05$), ** ($p < 0.01$), ***($p < 0.001$) and ns: not significant ($p > 0.05$).

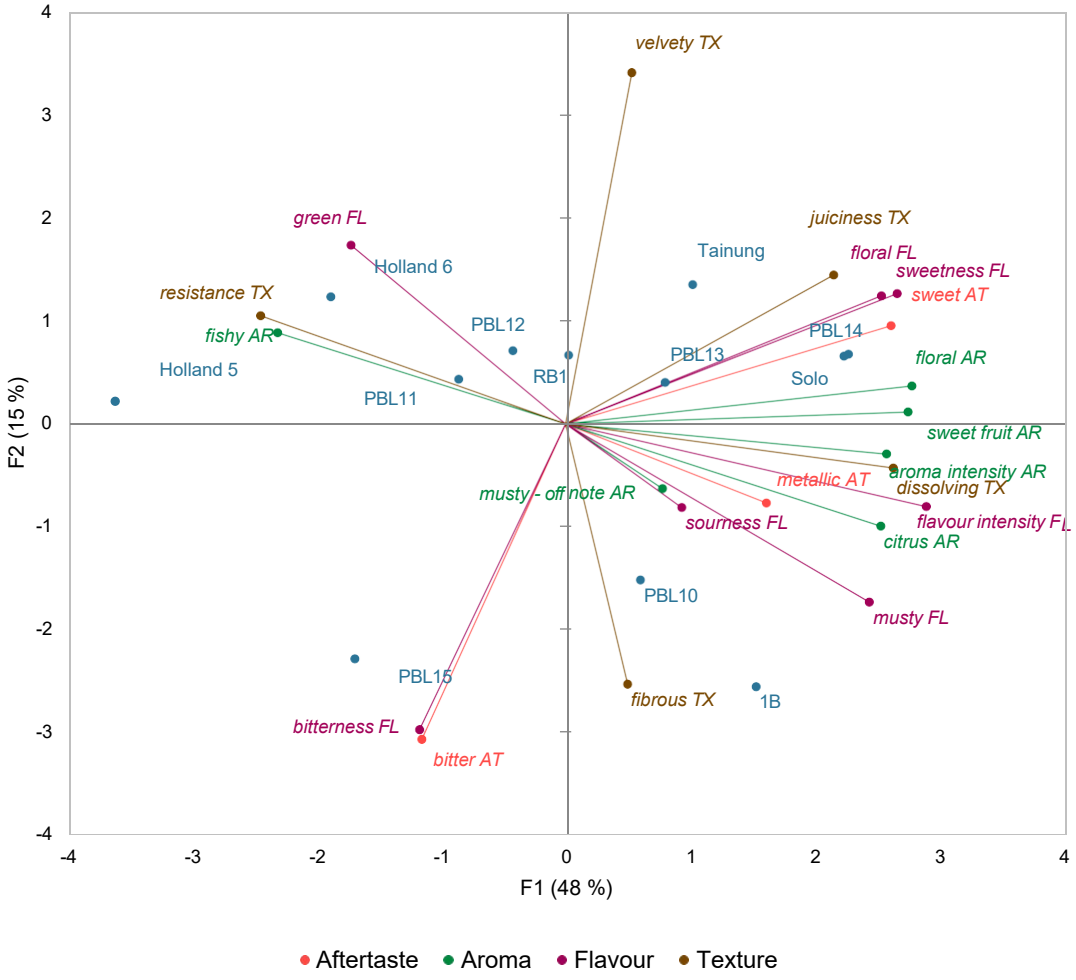
AR, aroma attributes; TX, texture attributes; FL, flavour attributes; AT, aftertaste attributes.

**Table 6** shows the F ratios and significance of the effects of sample (fixed), panellist (random) and replicate (random). A significant effect of sample was observed in all attributes, suggesting that panel was able to discriminate the intrinsic sensory difference among samples. No significant differences occurred in the attributes: *green aroma, other aroma, other flavour,* and *prickly aftertaste*, indicating that these were not important discriminators of these papaya samples. There were significant differences among all panellists for each attribute, indicating that panellists were using attributes differently which is typical of sensory data. For most of the attributes, there were no significant differences in how they were rated between each replicate, which suggests that the panellists rated most attributes consistently throughout the replicates. The attributes that with significant differences were *musty - off note aroma*, *resistance texture, dissolving texture, flavour intensity, musty flavour, green flavour, bitter aftertaste.* Differences in these attributes could be due to inconsistent use of these attributes by the panellists across different sessions.

## Sensory profiles of 12 papaya varieties evaluated by descriptive sensory analysis

A PCA bi-plot of the sensory scores (n=12) is given in **Figure 3**. The mean score for each sensory attributes is summarised in Appendix 4.

*Figure 3: PCA bi-plot of the sensory descriptive data for 12 papaya samples*




Within the first two principal components of the PCA, 63% of the variation was explained. The positive F1 is featured with most aroma and flavour attributes plus texture attributes *juiciness* and *dissolving*, while the negative F1 is featured with *resistance* texture and *fishy* aroma. The positive F2 is featured with *velvety* texture, while the negative F2 is featured with *fibrous* texture, *bitterness* flavour/aftertaste.

The commercial varieties RB1, 1B, Holland groups (5 and 6), Solo and Tainung are distinct in terms of overall sensory characteristics.

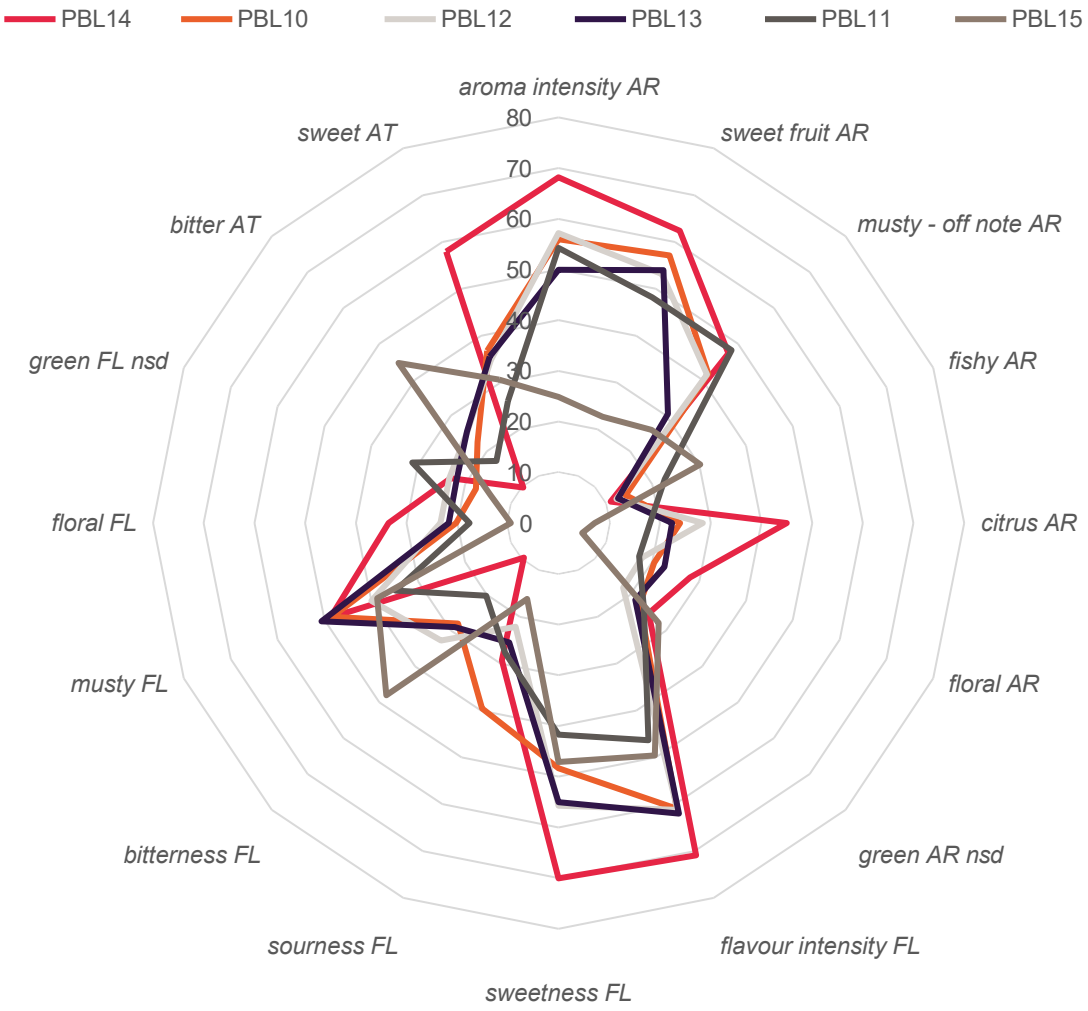
The varieties PBL13 and PBL14 showed similar sensory characteristics as Tainung and Solo, which had high scores for *aroma intensity*, *sweet fruit* aroma, *floral* aroma/flavour, *sweetness* flavour/aftertaste and *juiciness* texture (see also Figure 4 and Figure 5). Variety PBL14 had almost identical overall sensory characteristics as Solo.

The inbred varieties PBL11 and PBL12 was similar in overall sensory characteristics to RB1 and Holland varieties. PBL11 had an obvious *fishy* aroma and scored high for *resistance* texture as did Holland 5 and 6 (see also Figure 4 and Figure 5). PBL12 also had high scores for *resistance* texture but was not significantly different in *fishy* aroma (Appendix 4).

The inbred variety PBL15 was quite different from all other varieties. It showed the highest scores for *bitterness* taste/aftertaste, lowest scores for aroma attributes, lowest *velvety* and lowest *juiciness* scores

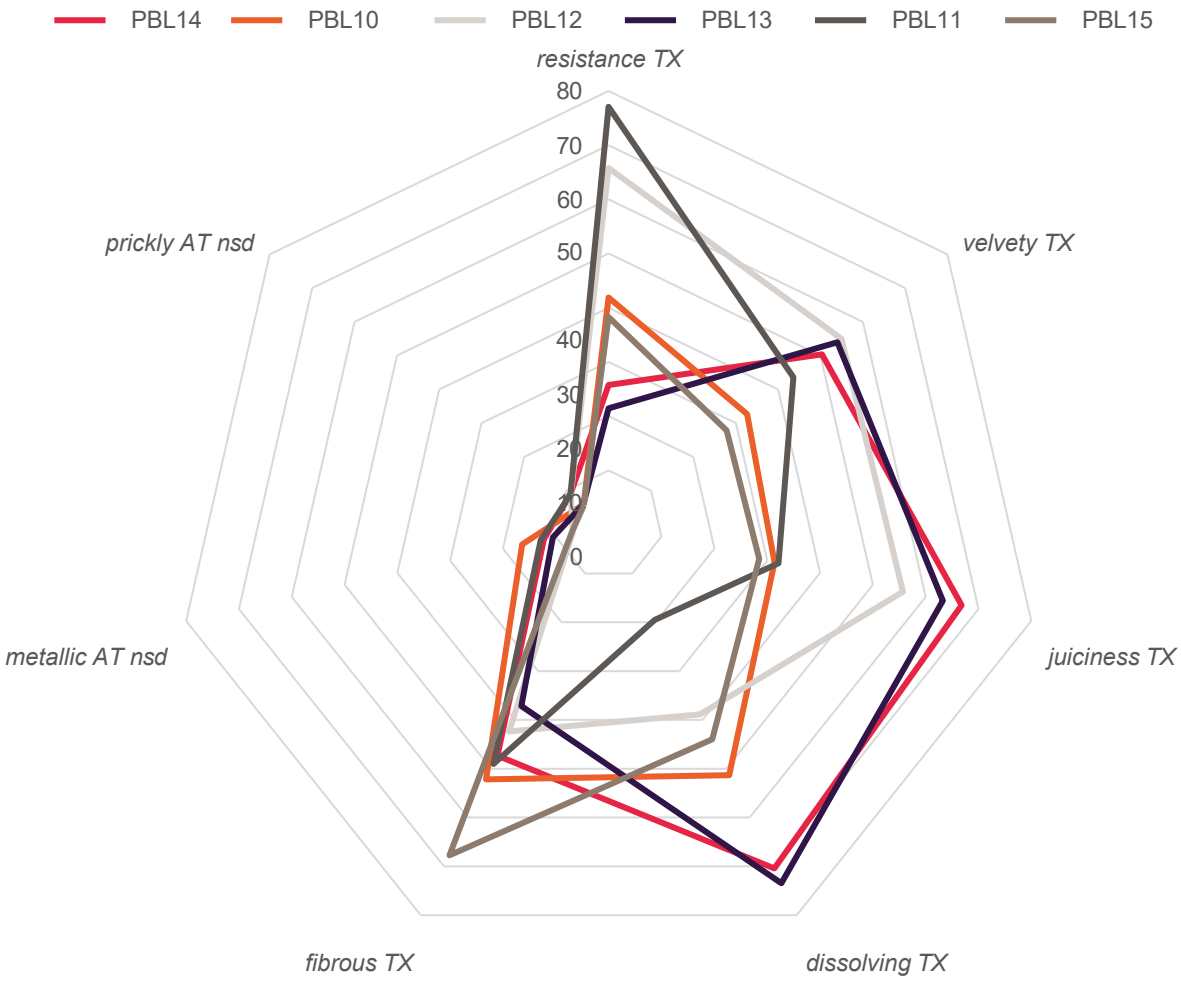
among all the samples. The inbred variety PBL10 had similar overall sensory characteristics as 1B, which were both high in *aroma intensity, dissolving* and *fibrous*, although PBL10 was low in *velvety* texture.

*Figure 4: Cobweb plot comparing aroma and flavour profiles for the new cultivars*




nsd = no significant difference by ANOVA (p>0.05)

*Figure 5: Cobweb plot comparing texture profiles for the new cultivars*




nsd = no significant difference by ANOVA (p>0.05)

# Conclusion

A descriptive analysis sensory study was successfully carried out for the August harvest 2022. Twelve samples were evaluated by conventional descriptive profiling with a trained sensory panel.

The commercial papaya varieties generally had higher scores for individual specific aroma and flavour attributes than the inbred varieties which made them more distinctive. Both PBL13 and PBL14 showed similar high scoring of *aroma intensity*, *sweet fruit* aroma, *floral* aroma/flavour, *sweetness* flavour/aftertaste and *juiciness* texture compared with commercial varieties Tainung and Solo. The inbred variety PBL11 was scored high for *fishy* aroma and *resistance* texture as was Holland 5 and 6, while PBL12 had similar high scores for *resistance* texture compared to Holland 5 and 6 but was scored lower for *fishy* aroma. The inbred variety PBL15 had high *bitterness* taste/aftertaste scored, received the lowest scores for all aroma attributes, and the lowest scored for *velvety* and *juiciness*. The inbred variety PBL10 had high aroma intensity scores, and high scores for *dissolving* and *fibrous* texture as commercial variety 1B, however, PBL10 was scored low for *velvety* texture.

# Appendices

*Appendix 1 Papaya sample set for formal testing (n=12)*

PBL10

PBL11

PBL13

PBL14

PBL15

PBL12

1B

RB1 (G4)

Holland 5 (G6)

Holland 6 (G7)

Tainung (G8)

Solo (G11)

*Appendix 2 Photographs of papaya half samples (n=12) for formal testing*

PBL10 PBL11 PBL13 PBL14

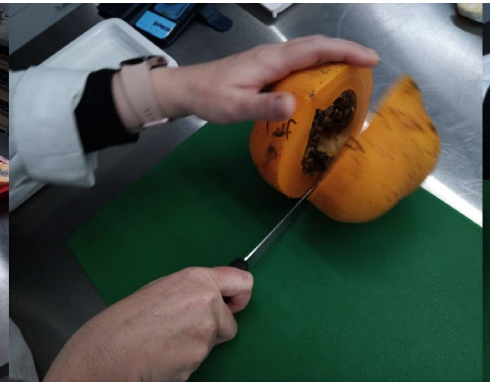

PBL15 PBL12 1B RB1 (G4)


Holland 5 (G6) Holland 6 (G7) Tainung (G8) Solo (G11)

*Appendix 3: Method of cutting papaya samples*

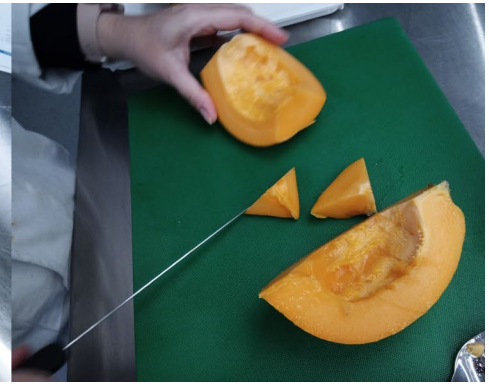
Step 1: Wash papaya with water

Step 2: Cut papaya in half



Step 3: Remove seeds from papaya half

Step 4: Cut papaya half into quarters and remove top and bottom wedge



Step 5: Cut quarters into slivers

Step 6: Remove skin off slivers

Step 7: Remove core flesh from slivers

Step 8: Cut slivers into cubes

*Appendix 4 Mean scores of sensory descriptors for the 12 papaya samples.*

| | *aroma intensity AR* | *sweet fruit AR* | *musty - off note AR* | *fishy AR* | *citrus AR* | *floral AR* | *green AR* | *resistance TX* | *velvety TX* | *juiciness TX* | *dissolving TX* | *fibrous TX* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1B | 82 E | 58 BC | 63 D | 15 AB | 58 G | 23 CD | 25 A | 19 A | 44 ABC | 67 DE | 75 D | 49 AB |
| PBL14 | 68 D | 62 C | 45 C | 11 A | 48 FG | 26 CD | 26 A | 27 ABC | 49 CD | 66 DE | 70 D | 48 AB |
| Solo (G11) | 62 CD | 61 BC | 34 ABC | 10 A | 40 EF | 39 D | 21 A | 23 ABC | 57 CD | 75 E | 71 D | 57 BC |
| PBL10 | 57 BCD | 58 BC | 40 ABC | 13 AB | 25 CDE | 19 C | 22 A | 42 D | 32 AB | 31 A | 52 BC | 53 ABC |
| RB1 (G4) | 52 BC | 35 A | 44 C | 50 E | 8 AB | 8 AB | 23 A | 34 BCD | 63 D | 68 DE | 64 CD | 46 AB |
| PBL12 | 56 BCD | 52 BC | 40 BC | 13 AB | 30 DE | 15 BC | 19 A | 65 E | 57 CD | 55 CD | 40 B | 43 AB |
| PBL13 | 51 BC | 55 BC | 28 AB | 13 AB | 24 CDE | 22 C | 21 A | 20 AB | 54 CD | 62 DE | 74 D | 38 A |
| PBL11 | 56 BCD | 50 BC | 47 C | 24 ABC | 19 BCD | 17 BC | 23 A | 77 EF | 46 BC | 32 AB | 20 A | 49 AB |
| Tainung (G8) | 54 BCD | 49 B | 39 ABC | 19 AB | 21 BCD | 24 CD | 25 A | 26 ABC | 60 CD | 64 DE | 71 D | 42 A |
| Holland 6 (G7) | 41 AB | 29 A | 43 BC | 45 DE | 11 ABC | 4 A | 24 A | 78 F | 57 CD | 45 BC | 23 A | 36 A |
| Holland 5 (G6) | 28 A | 27 A | 36 ABC | 39 CDE | 5 A | 3 A | 29 A | 82 F | 48 C | 38 AB | 18 A | 40 A |
| PBL15 | 25 A | 23 A | 25 A | 27 BCD | 8 AB | 5 AB | 25 A | 38 CD | 26 A | 27 A | 42 B | 67 C |

| | *flavour intensity FL* | *sweetness FL* | *sourness FL* | *bitterness FL* | *musty FL* | *floral FL* | *green FL* | *bitter AT* | *sweet AT* | *metallic AT* | *prickly AT* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1B | 74 F | 41 B | 17 AB | 61 G | 59 D | 23 BCD | 22 AB | 52 D | 27 BC | 14 A | 8 A |
| PBL14 | 70 EF | 69 E | 30 BC | 9 A | 47 CD | 31 DE | 24 AB | 9 A | 57 E | 13 A | 8 A |
| Solo (G11) | 64 DEF | 64 DE | 19 AB | 18 ABC | 40 BC | 46 E | 20 A | 19 AB | 45 DE | 14 A | 7 A |
| PBL10 | 60 CDE | 46 BC | 42 C | 27 BCDEF | 47 CD | 16 ABCD | 19 A | 23 B | 34 BCD | 17 A | 6 A |
| RB1 (G4) | 55 BCD | 56 CDE | 11 A | 37 DEF | 45 CD | 20 BCD | 24 AB | 29 BC | 36 BCD | 8 A | 5 A |
| PBL12 | 60 CDE | 54 BCD | 23 AB | 30 CDEF | 38 BC | 20 BCD | 25 AB | 22 AB | 36 BCD | 7 A | 7 A |
| PBL13 | 61 DE | 54 BCD | 27 B | 26 BCD | 49 CD | 22 BCD | 23 AB | 24 B | 35 BCD | 9 A | 5 A |
| PBL11 | 45 B | 41 B | 28 BC | 18 ABC | 37 ABC | 17 ABCD | 33 BC | 16 AB | 25 B | 14 A | 8 A |
| Tainung (G8) | 58 CDE | 62 DE | 13 A | 15 AB | 40 BC | 30 CDE | 23 AB | 14 AB | 43 CDE | 13 A | 7 A |
| Holland 6 (G7) | 45 B | 42 B | 16 AB | 26 BCDE | 30 AB | 13 ABC | 27 ABC | 21 AB | 25 B | 11 A | 8 A |
| Holland 5 (G6) | 24 A | 14 A | 17 AB | 44 EFG | 21 A | 6 A | 38 C | 41 CD | 4 A | 8 A | 8 A |
| PBL15 | 48 BC | 45 BC | 17 AB | 47 FG | 37 BC | 9 AB | 15 A | 43 CD | 30 BCD | 7 A | 6 A |

Different letters within one column indicate significant difference (Tukey's ANOVA post-hoc test at a significant level $p < 0.05$).

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*9 September 2022*

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QAAFI
Queensland Alliance for Agriculture and Food Innovation

# PP1800: National Papaya Breeding and Evaluation Program. Market preferred papaya flavours and other sensory types

Report on sensory evaluation of 2023 season fruits

The Queensland Alliance for Agriculture and Food Innovation (QAAFI) is a research institute of The University of Queensland (UQ), supported by the Queensland Government

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# Project Objectives

The main objectives of this project were:

- To obtain sensory profiles of advanced papaya breeding lines
- To compare the sensory properties of advanced papaya breeding lines with commercial papaya varietals

# Material and Methods

## Approach

A trained panel study (descriptive profiling) was conducted for the papaya varieties in February 2023:

## Sample preparation

Papaya samples were delivered by the client the week prior to sensory training and/or formal evaluation with the trained panel. Depending on fruit ripeness level, the papaya samples were stored at either 12°C (ripe), 15°C (nearly ripe), or at room temperature (22°C) (not ripe at all). One delivery of fruit, at each harvest time, was used for the entire duration of each separate sensory trial.

Papaya samples were prepared on the morning of each tasting session by cutting whole fruit in half, removing seeds and skin with a knife, and cutting the flesh into cubes (~1.5-2.0 $cm^3$). Cubes of fruit (~15-20 g) were dispensed into porcelain cups (50 ml size), labelled with a 3-digit code, covered with an aluminium foil and stored at room temperature until use (**Figure 1**). The photos of whole papayas and halved papayas are in Appendix 1. A detailed method of cutting papaya samples can be seen in Appendix 2. Individual fruits were used for each replicate in formal evaluations. The papaya varieties used for the sensory evaluation are listed in **Table 2**.

*Figure 1: Photograph of prepared papaya samples used for sensory evaluation*

*Table 2: List of papaya varieties assessed in sensory evaluation with trained panel*

| Sample # | Variety group | Commercial variety? | Papaya variety |
|---|---|---|---|
| 1 | PBL8 | Breeding Line | Red F6 |
| 2 | Sunlight 3 | Output from breeding project (PP18000) | Red F6 |
| 3 | PBL9 | Breeding Line | Red F6 |
| 4 | PBL6 | Breeding Line | Red F6 |
| 5 | PBL7 | Breeding Line | Red F6 |
| 6 | RB1 | Commercial Cultivar | Red commercial |

## Descriptive profiling

Nine trained sensory panellists (six female and three male) participated in the study, aged between 22 and 60 years (with an average age of 41). These panellists were sourced from a pool of experienced trained assessors who had previously been screened for sensory acuity and were experienced in trials involving tropical fruit.

Conventional quantitative sensory descriptive analysis method was used to characterise the sensory properties of the six papaya samples with four repetitions. Due to the limited fruit samples, all training and formal evaluations were conducted over two, two-hour sessions.

The training involved familiarising the panellists with the samples; developing an assessment protocol, developing a concise vocabulary to describe the sensory properties of the samples; defining the sensory attributes; developing corresponding sensory reference standards and developing scales and anchors for rating the attributes. All samples were introduced to the panellists at least once during training.

Formal evaluation sessions were conducted in one and a half days, completing four replicates of all papaya samples. A balanced sample presentation was used within each replicate for all trials. In each session, panellists were asked to go through the definitions of the attributes and re-assess the sensory reference standards before assessing samples. The method developed for assessment is detailed as follows:

- *Lift lid to assess aroma*
- *Using a metal two-pronged fork to lift the fruit, assess whole fruit cubes*
- *Sample one full cube of fruit to assess texture*
- *Sample another full cube of fruit to assess flavour and aftertaste*
- *If required, sample the third full cube of fruit*
- *Rinse palate with water and rest for at least 30 seconds, before assessing next sample.*

The sensory properties rated included 6 aroma, 5 texture, 5 flavour and 4 aftertaste attributes. Other aroma and other flavour attributes were also included for panellists to rate and describe if any other sensory properties were perceived during the tasting. The sensory attributes, together with their definitions and composition of the sensory reference standards are detailed in **Table 3**. All attributes were rated on unstructured line scales (0-100), anchored from 'none' to 'high'. Within a 2-hour session, a maximum of 18 samples were presented with forced 2-minute breaks between samples. Data were collected electronically using the software RedJade (RedJade Software Solutions, LLC, Tragon Corporation, California, USA, 2021).

*Table 3: Sensory attributes and definitions used in the sensory descriptive study*

| Attribute* | Definition | Reference Standard |
|---|---|---|
| ***Aroma*** | | |
| *aroma intensity* | The overall aroma intensity from none to high | n/a |
| *sweet fruit* | Aroma of fresh sweet fruit such as honeydew melon or mango | ~1x2 $cm^3$ cut honeydew melon piece w/o skin, 1ml orange juice (Golden Circle, no added sugar, Orange Juice, long life) |
| *musty- off note* | Aroma of ripe rock melon, over-ripe fruit, sulphurous, fermented | ~1x2 $cm^3$ cut rock melon piece w/ skin |
| *fishy* | Aroma of tune, fishy, or seaweed | ~0.5 $cm^3$ piece canned tuna (Aldi Ocean Rise Yellowfin tuna in Springwater) |
| *citrus* | Aroma of citrus peel or juice | 1 cm each string of rind from an orange, mandarin and lemon |
| *floral* | Floral notes (Jasmine flower) | ¼ drop of Jasmine flower essence (Aromaster Wine Kit bottle #24) |
| *other* | Any other aroma (please describe) | n/a |
| ***Texture*** | | |
| *resistance* | Degree to which sample resists initial bite, firmness, could be crisp when high | n/a |
| *velvety* | Smoothness of sample during initial 2-3 bites (lack of particles/grit), silky smooth is high | n/a |
| *juiciness* | Degree to which liquid is released on mastication (first 2-3 bites) | n/a |
| *dissolving* | Degree to which sample dissolves/disintegrates in the mouth | n/a |

| Attribute* | Definition | Reference Standard |
|---|---|---|
| *fibrous* | Presence of fibrous pieces, debris | n/a |
| ***Flavour*** | | |
| *flavour intensity* | The overall flavour intensity from none to high | n/a |
| *sweetness* | Sweet flavour associated with cooked sweet potato/carrot, sweet melon with caramel notes, confectionary | 25 g/L sucrose solution |
| *bitterness* | Bitter flavour | 0.3 g/L caffeine solution |
| *musty* | Flavour of over-ripe rockmelon with skin, stale | As for aroma |
| *floral* | Floral notes (Jasmine flower) | As for aroma |
| *other* | Any other flavour (please describe) | n/a |
| ***Aftertaste*** | | |
| *bitter* | Bitter aftertaste | As above in flavour |
| *sweet* | Sweet aftertaste | As above in flavour |
| *metallic* | Metallic aftertaste | n/a |
| *prickly* | Tingle or heat of pepperiness | n/a |

All attribute scales anchored none-high. All training sessions were conducted in a meeting room equipped with an electronic whiteboard. Practice and formal evaluation sessions were held in the purpose-build sensory evaluation laboratory facility at the Elkhorn Building, UQ Long Pocket Campus. The laboratory is equipped with 14 isolated sensory booths, iPads, temperature controlling (22°C) and LED light controlling (day-light equivalent lighting) (**Figure 2**).

## Data analysis

Data was exported from RedJade into Microsoft Excel for analysis. XLSTAT (2022.2.1, Paris, France) was used to analyse panellist performance, for product characterisation and data exploration and analysis.

### Descriptive profiling

For all sensory attributes, descriptive statistics on the scores was calculated including minimum, maximum, mean, standard deviation, coefficient of variation (CV), and standard error of the mean (SEM).

For testing discrimination power and repeatability of the panellists, Analysis of Variance (ANOVA) was performed on the sensory scores provided by each panellist; the ANOVA model used for testing discrimination

power was attribute = F(product) and that for repeatability was attribute = F(session). The panellist's agreement with the entire panel was calculated as attribute = F(panellist x product). A mixed model ANOVA, with product as the fixed effect and panellists, sessions and pair-wise interactions between product and panellist, panellist and session and session and product as random effects is conducted on the whole dataset for each attribute ($p < 0.05$).

The mean score of all the sensory attributes for each product was calculated and a Tukey HSD was conducted to evaluate whether the products were significantly different from each other based on the attributes ($p < 0.05$). Finally, a principal component analysis (PCA) was performed on the mean scores for all samples to visually observe sample differentiation. The sensory attributes without significant differences across products were not included in the PCA.

*Figure 2: Photographs of formal evaluation sessions*

# Results and Discussion

## Descriptive profiling

### Panel performance and quality of sensory data

To explore the sensory scores and determine panel performance, the mean, maximum, minimum, standard deviation standard error of the mean and coefficient of variation of each of the sensory attributes rated by the panel of 10 across the 6 papaya samples were calculated as shown in **Table 4**.

*Table 4: Summary of the descriptive analysis scores (n= 6 samples x 4 replicates x 9 panellists)*

| | Min | Max | Mean | SD | CV% | SEM |
|---|---|---|---|---|---|---|
| *aroma intensity AR* | 46 | 71 | 53 | 25 | 46 | 1.7 |
| *sweet fruit AR* | 15 | 38 | 22 | 24 | 109 | 1.6 |
| *musty - off note AR* | 38 | 63 | 46 | 30 | 64 | 2.0 |
| *fishy AR* | 20 | 56 | 41 | 32 | 77 | 2.1 |
| *citrus AR* | 5 | 21 | 11 | 19 | 183 | 1.3 |
| *floral AR* | 3 | 50 | 20 | 28 | 139 | 1.9 |
| *resistance TX* | 25 | 59 | 43 | 28 | 65 | 1.9 |
| *velvety TX* | 41 | 65 | 53 | 27 | 52 | 1.9 |
| *juiciness TX* | 34 | 71 | 54 | 25 | 47 | 1.7 |
| *dissolving TX* | 42 | 73 | 56 | 26 | 46 | 1.8 |
| *fibrous TX* | 25 | 64 | 48 | 28 | 58 | 1.9 |
| *flavour intensity FL* | 59 | 73 | 66 | 17 | 26 | 1.2 |
| *sweetness FL* | 36 | 72 | 60 | 24 | 39 | 1.6 |
| *bitterness FL* | 22 | 70 | 35 | 32 | 92 | 2.1 |
| *musty FL* | 34 | 53 | 43 | 28 | 66 | 1.9 |
| *floral FL* | 15 | 58 | 29 | 30 | 103 | 2.0 |
| *bitter AT* | 17 | 65 | 31 | 31 | 102 | 2.1 |
| *sweet AT* | 19 | 53 | 39 | 29 | 71 | 2.0 |
| *metallic AT* | 14 | 25 | 18 | 26 | 140 | 1.8 |
| *prickly AT* | 9 | 18 | 15 | 24 | 163 | 1.6 |

*Suffixes: AR, aroma attributes; TX, texture attributes; FL, flavour attributes; AT, aftertaste attributes.*

*SD, Standard deviation; CV, Variation coefficient; SEM, Standard error of the mean.*

Analysis of variance was conducted to evaluate the panel performance (**Table 5**). Discrimination power shows the number of attributes panellists were able to discriminate among samples, while repeatability indicates the number of attributes panellists were able to discriminate consistently throughout the four replicates. Overall,

the panel performance was average, probably due to the reduced practice sessions which is not ideal. However, this was necessary due to the limited fruit available for the study.

*Table 5: Summary of panellist performance, discrimination power and repeatability determined from an ANOVA model of the sensory data obtained for samples. (n=6 samples x 4 replicates x 9 panellists)*

| Panellist | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Discrimination | 6 | 9 | 3 | 4 | 3 | 6 | 6 | 5 | 4 |
| Repeatability | 14 | 14 | 16 | 12 | 16 | 16 | 12 | 13 | 16 |
| Total | 20 | 23 | 19 | 16 | 19 | 22 | 18 | 18 | 20 |

The discrimination power denotes the total number of attributes for which there is a significant difference ($p < 0.05$) across all the samples; repeatability denotes the number of attributes for which there is no significant difference ($p < 0.05$) across the four replicates for the same product. The ideal value for Total is 28

*Table 6: F-ratios and significance for effects of 6 samples, panellist and replicate (4 replicates x 9 panellists)*

| Sensory attribute | Sample | Panellist | Replicate |
|---|---|---|---|
| *aroma intensity AR* | 3* | 4** | 0 |
| *sweet fruit AR* | 6** | 11*** | 2 |
| *musty - off note AR* | 3* | 5*** | 1 |
| *fishy AR* | 8*** | 15*** | 4* |
| *citrus AR* | 3* | 13*** | 0 |
| *floral AR* | 8*** | 5*** | 0 |
| *resistance TX* | 3* | 3* | 1 |
| *velvety TX* | 2** | 3* | 1 |
| *juiciness TX* | 8*** | 3* | 2 |
| *dissolving TX* | 3* | 6** | 1 |
| *fibrous TX* | 10*** | 3* | 2 |
| *flavour intensity FL* | 1* | 3* | 1 |
| *sweetness FL* | 4** | 2 | 0 |
| *bitterness FL* | 4* | 6** | 1 |

| Sensory attribute | Sample | Panellist | Replicate |
|---|---|---|---|
| *musty FL* | 1 | 6*** | 1 |
| *floral FL* | 8*** | 6*** | 0 |
| *bitter AT* | 4* | 4** | 0 |
| *sweet AT* | 3* | 7*** | 0 |
| *metallic AT* | 3 | 20*** | 1 |
| *prickly AT* | 2 | 17*** | 0 |

*Significant F-ratios are indicated by * ($p < 0.05$), ** ($p < 0.01$), ***($p < 0.001$) and ns: not significant ($p > 0.05$).*

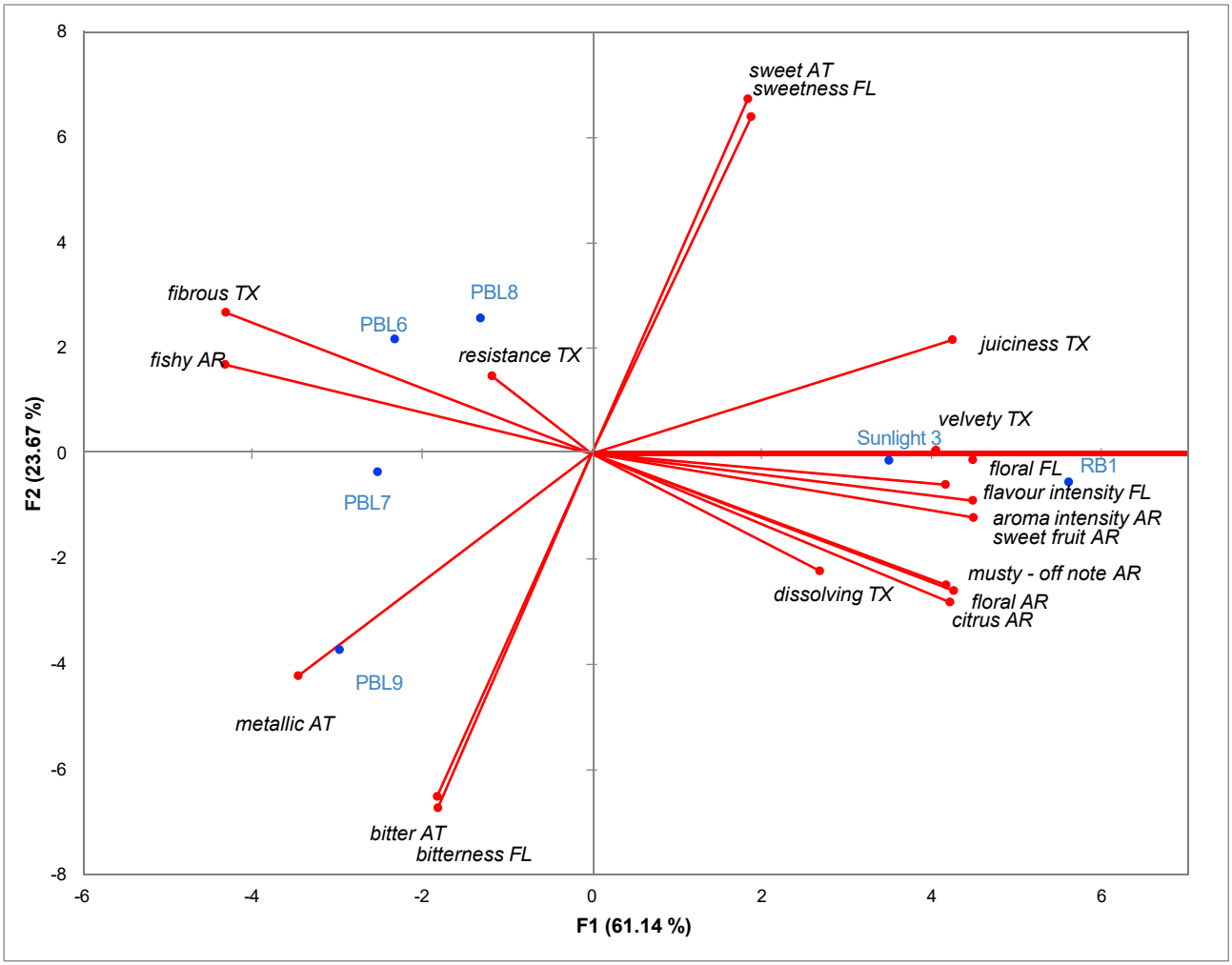
*AR, aroma attributes; TX, texture attributes; FL, flavour attributes; AT, aftertaste attributes.*

**Table 6** shows the F ratios and significance of the effects of sample (fixed), panellist (random) and replicate (random). A significant effect of sample was observed in majority of the attributes, suggesting that panel was able to discriminate the intrinsic sensory differences among the papaya samples. No significant differences occurred in the attributes: *musty flavour, metallic aftertaste and prickly aftertaste*, indicating that these were not important discriminators of these papaya samples. There were significant differences among all panellists for each attribute, indicating that panellists were using attributes differently which is typical of sensory data. For most of the attributes, there were no significant differences in how they were rated between each replicate, which suggests that the panellists rated most attributes consistently throughout the replicates. Only *fishy aroma* was significantly differently which could be due to inconsistent use of this attribute by the panellists across different sessions or inconsistency in the different papaya samples used.

## Sensory profiles of 12 papaya varieties evaluated by descriptive sensory analysis

A PCA bi-plot of the sensory scores (n=6) is given in **Figure 3**. Within the first two principal components of the PCA, 84% of the variation was explained. Sample Sunlight 3 and RB1 were the most similar to each other having high *aroma intensity*, with *floral, sweet fruit, musty* and *citrus* being the dominant aromas. These samples were also high in *flavour intensity*, being very *sweet*, which lingered after swallowing as well. These two papaya samples were also more *velvety, juicy,* and *dissolving* in terms of textural properties. Samples PBL8 and PBL6 were also high in *sweetness flavour* and *sweet aftertaste*, but were more *resistant, fibrous* and had a stronger *fishy aroma* compared to the other samples. Lastly samples PBL7 and PBL9 were high in *bitterness flavour*, *bitter aftertaste*, and *metallic aftertaste*, as well as being *resistant, fibrous,* and *fishy,* like samples PBL6 and PBL8.

*Figure 3: PCA bi-plot of the sensory descriptive data for 6 papaya samples (n= 4 replicates x 9 panellists)*




# Conclusion

A descriptive analysis sensory study was successfully carried out for the February 2023 harvest. Six samples were evaluated by conventional descriptive profiling with a trained sensory panel. Among the six papaya samples, there were quite some differences perceived by the trained panel. In particular, samples Sunlight 3 and RB1 had stronger aromas and flavours and were more velvety and dissolving. The remaining samples were quite similar being more fibrous, resistant and fishy, though samples PBL8 and PBL6 were sweet, while samples PBL9 and PBL7 were bitter.

# Appendices

*Appendix 1: Photographs of papaya half samples (n=6) for formal testing*

PBL8


Sunlight 3


PBL9


PBL6


PBL7


RB1

*Appendix 2: Method of cutting papaya samples*

Step 1: Wash papaya with water

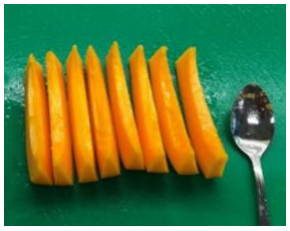
Step 2: Cut papaya in half

Step 3: Remove seeds from papaya half

Step 4: Cut papaya half into quarters

Step 5: Remove top and bottom wedge

Step 6: Cut quarters into slivers



Step 7: Remove skin off slivers

Step 8: Cut slivers into cubes

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*21 February 2024*

# AS19003: Genetics of fruit sensory preferences

Report on sensory evaluation of 2023/24 season fruits

The Queensland Alliance for Agriculture and Food Innovation (QAAFI) is a research institute of The University of Queensland (UQ), supported by the Queensland Government

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# Project Objectives

The main objectives of this project deliverable was to:

- To obtain sensory profiles of papaya breeding lines and commercial papayas
- To compare the sensory properties of commercially available papaya from overseas and Australia, with papaya advanced breeding lines and new papaya breeds which emerged from project PP18000.

# Material and Methods

## Approach

A trained panel study (descriptive profiling) was conducted for the papaya varieties in February 2024:

## Sample preparation

Papaya samples were delivered by the client in the days prior to sensory training and/or formal evaluation with the trained panel. Depending on fruit ripeness level, the papaya samples were stored at either 12°C (ripe), 15°C (nearly ripe), or at room temperature (22°C) (not ripe at all). One delivery of fruit, at each harvest time, was used for the entire duration of each separate sensory trial.

Papaya samples were prepared on the morning of each tasting session by cutting whole fruit in half, removing seeds and skin with a knife, and cutting the flesh into cubes (~1.5-2.0 $cm^3$). Cubes of fruit (~15-20 g) were dispensed into porcelain cups (50 ml size), labelled with a 3-digit code, covered with an aluminium foil and stored at room temperature until use (**Figure 1**). The photos of whole papayas and halved papayas are in Appendix 1. A detailed method of cutting papaya samples can be seen in Appendix 2. Individual fruits were used for each replicate in formal evaluations. The 12 papaya varieties used for this sensory descriptive profiling evaluation are listed in **Table 3**.

*Figure 1: Photograph of prepared papaya samples used for sensory evaluation*

*Table 3: List of papaya varieties assessed in sensory evaluation with trained panel*

| Sample # | Variety group | Commercial variety? (Land of origin) | Papaya variety |
|---|---|---|---|
| 1 | Eksotika | Yes (Malaysia) | Orange-red |
| 2 | F1 Malay | Yes (Malaysia) | Red |
| 3 | RB1 | Yes (Australia) | Red |
| 4 | Holland 5 | Yes (Malaysia) | Red |
| 5 | First Lady | Yes (Thailand) | Red |
| 6 | PBL16 | Advanced breeding line | Red hybrid (PBL2 x Solo) |
| 7 | PBL21 | Advanced breeding line | Red hybrid (PBL4 x Solo) |
| 8 | PBL1 | Advanced breeding line | Red F7 |
| 9 | PBL3 | Advanced breeding line | Red F7 |
| 10 | PBL4 | Advanced breeding line | Red F7 |
| 11 | Sunlight 1 | Output from breeding project (PP18000) | Red F7 |
| 12 | Sunlight 2 | Output from breeding project (PP18000) | Red F7 |

## Descriptive profiling

Eleven trained sensory panellists (nine female and two male) participated in the study, aged between 27 and 61 years (with an average age of 47). These panellists were sourced from a pool of experienced trained assessors who had previously been screened for sensory acuity and were experienced in trials involving tropical fruit.

Conventional quantitative sensory descriptive analysis method was used to characterise the sensory properties of the 12 papaya samples with four repetitions. All training and formal evaluations were conducted over seven, two-hour sessions.

The training involved familiarising the panellists with the samples; developing and/or optimising the assessment protocol which was developed in previous studies of the PP18000 project, as well as developing and/or optimising vocabulary to describe the sensory properties of the samples; including defining the sensory attributes and corresponding sensory reference standards. Furthermore, scales and anchors for rating the sensory attributes were defined. All samples were introduced to the panellists at least once during training.

Formal evaluation sessions were conducted in two days, completing four replicates of all papaya samples. A balanced sample presentation was used within each replicate for all trials. In each session, panellists were asked to go through the definitions of the attributes and re-assess the sensory reference standards before assessing samples. The method developed for assessment is detailed as follows:

- *Lift lid to assess aroma*
- *Using a metal two-pronged fork to lift the fruit, assess whole fruit cubes*
- *Sample one full cube of fruit to assess texture*
- *Sample another full cube of fruit to assess flavour and aftertaste*
- *If required, sample the third full cube of fruit*
- *Rinse palate with water and rest for at least 30 seconds, before assessing next sample.*

The sensory properties rated included 8 aroma, 5 texture, 7 flavour and 4 aftertaste attributes. Other aroma and other flavour attributes were also included for panellists to rate and describe if any other sensory properties were perceived during the tasting. The sensory attributes, together with their definitions and composition of the sensory reference standards are detailed in **Table 4**. All attributes were rated on unstructured line scales (0-100), anchored from ‘none’ to ‘high’. In the final evaluation sessions, a maximum of 18 samples were presented with forced 2-minute breaks between samples. Data were collected electronically using the software RedJade (RedJade Software Solutions, LLC, Tragon Corporation, California, USA, 2021).

*Table 4: Sensory attributes and definitions used in the sensory descriptive study*

| Attribute* | Definition | Reference Standard |
|---|---|---|
| ***Aroma*** | | |
| *aroma intensity* | The overall aroma intensity from none to high | n/a |
| *sweet fruit* | Aroma of fresh sweet fruit such as honeydew melon or mango | ~1x2 $cm^3$ cut honeydew melon piece w/o skin |
| *musty- off note* | Aroma of overripe rock melon, over-ripe fruit, sulphurous, fermented | ~1x2 $cm^3$ cut rock melon piece w/ skin |
| *fishy* | Aroma of tuna, fishy, or seaweed | ~0.5 $cm^3$ piece canned tuna (John West tuna in Springwater) |
| *citrus* | Aroma of citrus peel or juice | 1 cm each string of rind from an orange, mandarin and lemon |
| *floral* | Floral notes (Jasmine flower) | ¼ drop of Jasmine flower essence (Aromaster Wine Kit bottle #24) |
| *root vegetable* | Aroma of raw root vegetables (carrot, pumpkin, sweet potato) | Grated raw carrot, pumpkin and sweet potato, and ½ tsp roasted carrot, pumpkin and sweet potato puree |
| *green* | Aroma of cucumber, fresh grass, green tea | 1x 2 cm3 cut cucumber |
| *other* | Any other aroma (please describe) | n/a |
| ***Texture*** | | |
| *resistance* | Degree to which sample resists initial bite, firmness, could be crisp when high | n/a |
| *velvety* | Smoothness of sample during initial 2-3 bites (lack of particles/grit), silky smooth is high | n/a |
| *juiciness* | Degree to which liquid is released on mastication (first 2-3 bites) | n/a |
| *dissolving* | Degree to which sample dissolves/disintegrates in the mouth | n/a |
| *fibrous* | Presence of fibrous pieces, debris | n/a |
| ***Flavour*** | | |
| *flavour intensity* | The overall flavour intensity from none to high | n/a |
| *sweetness* | Sweet flavour associated with cooked sweet potato/carrot, sweet melon with caramel notes, confectionary | 25 g/L sucrose solution |
| *bitterness* | Bitter flavour | 0.3 g/L caffeine solution |
| *musty* | Flavour of over-ripe rockmelon with skin, stale | As for aroma |
| *floral* | Floral notes (Jasmine flower) | ¼ drop of Jasmine flower essence (Aromaster Wine Kit bottle #24) |
| *tropical fruit* | Tropical/citrus fruit flavour (pineapple, mango, passionfruit) | 1 tsp mango, passionfruit and pineapple puree with sucrose solution |
| *root vegetable* | Savoury flavour associated with cooked sweet potato/carrot/pumpkin | 1 tsp roasted pumpkin, carrot and sweet potato puree |
| *other* | Any other flavour (please describe) | n/a |
| ***Aftertaste*** | | |
| *bitter* | Bitter aftertaste | As above in flavour |
| *sweet* | Sweet aftertaste | As above in flavour |
| *metallic* | Metallic aftertaste | n/a |
| *prickly* | Tingle or heat of pepperiness | n/a |

All attribute scales anchored none-high. All training sessions were conducted in a meeting room equipped with an electronic whiteboard. Practice and formal evaluation sessions were held in the purpose-build sensory evaluation laboratory facility at the Elkhorn Building, UQ Long Pocket Campus. The laboratory is equipped with 14 isolated sensory booths, iPads, temperature controlling (22°C) and LED light controlling (day-light equivalent lighting) (**Figure** 2).

## Data analysis

Data was exported from RedJade into Microsoft Excel for analysis. XLSTAT (2022.2.1, Paris, France) was used to analyse panellist performance, for product characterisation and data exploration and analysis.

*Figure 2: Photographs of formal evaluation sessions*

### Descriptive profiling

For all sensory attributes, descriptive statistics on the scores was calculated including minimum, maximum, mean, standard deviation, coefficient of variation (CV), and standard error of the mean (SEM).

For testing discrimination power and repeatability of the panellists, Analysis of Variance (ANOVA) was performed on the sensory scores provided by each panellist; the ANOVA model used for testing discrimination power was attribute = F(product) and that for repeatability was attribute = F(session). The panellist's agreement with the entire panel was calculated as attribute = F(panellist x product). A mixed model ANOVA, with product as the fixed effect and panellists, sessions and pair-wise interactions between product and panellist, panellist and session and session and product as random effects is conducted on the whole dataset for each attribute ($p < 0.05$).

The mean score of all the sensory attributes for each product was calculated and a Tukey HSD was conducted to evaluate whether the products were significantly different from each other based on the attributes ($p < 0.05$). Finally, a principal component analysis (PCA) was performed on the mean scores for all samples to visually observe sample differentiation. The sensory attributes without significant differences across products were not included in the PCA.

# Results and Discussion

## Descriptive profiling

### Panel performance and quality of sensory data

To explore the sensory scores and determine panel performance, the mean, maximum, minimum, standard deviation standard error of the mean and coefficient of variation of each of the sensory attributes rated by the panel across twelve papaya samples were calculated as shown in **Table 5**.

*Table 5: Summary of the descriptive analysis scores (n= 12 samples x 4 replicates x 11 panellists)*

| Sensory Attributes | Min | Max | Mean | SD | CV% | SEM |
|---|---|---|---|---|---|---|
| *aroma intensity AR* | 9 | 100 | 52 | 27 | 52 | 1.2 |
| *sweet fruit AR* | 1 | 86 | 32 | 28 | 88 | 1.2 |
| *musty - off note AR* | 0 | 76 | 36 | 28 | 78 | 1.2 |
| *fishy AR* | 0 | 76 | 31 | 29 | 93 | 1.3 |
| *citrus AR* | 0 | 98 | 24 | 30 | 124 | 1.3 |
| *floral AR* | 0 | 94 | 25 | 31 | 122 | 1.4 |
| *root vegetable* | 0 | 84 | 28 | 26 | 91 | 1.1 |
| *green AR* | 0 | 68 | 25 | 26 | 106 | 1.1 |
| *resistance TX* | 4 | 84 | 40 | 28 | 70 | 1.2 |
| *velvety TX* | 5 | 78 | 38 | 25 | 64 | 1.1 |
| *juiciness TX* | 3 | 89 | 42 | 28 | 66 | 1.2 |
| *dissolving TX* | 8 | 98 | 58 | 28 | 48 | 1.2 |
| *fibrous TX* | 0 | 100 | 40 | 27 | 68 | 1.2 |
| *flavour intensity FL* | 16 | 100 | 56 | 22 | 40 | 1.0 |
| *sweetness FL* | 18 | 90 | 57 | 23 | 41 | 1.0 |
| *bitterness FL* | 0 | 72 | 18 | 22 | 118 | 0.9 |
| *musty FL* | 0 | 92 | 42 | 27 | 64 | 1.2 |
| *floral FL* | 0 | 94 | 29 | 30 | 102 | 1.3 |
| *tropical fruit FL* | 0 | 99 | 32 | 31 | 97 | 1.4 |
| *root vegetable FL* | 0 | 95 | 41 | 28 | 69 | 1.2 |
| *bitter AT* | 0 | 60 | 16 | 20 | 121 | 0.9 |
| *sweet AT* | 0 | 92 | 41 | 29 | 70 | 1.2 |
| *metallic AT* | 0 | 40 | 9 | 13 | 152 | 0.6 |
| *prickly AT* | 0 | 62 | 7 | 15 | 223 | 0.7 |

Suffixes: AR, aroma attributes; TX, texture attributes; FL, flavour attributes; AT, aftertaste attributes.

SD, Standard deviation; CV, Variation coefficient; SEM, Standard error of the mean.

Analysis of variance was conducted to evaluate the panel performance (**Table 6**). Discrimination power shows the number of attributes panellists were able to discriminate among samples, while repeatability indicates the number of attributes panellists were able to discriminate consistently throughout the four replicates. The discrimination power denotes the total number of attributes for which there is a significant difference ($p < 0.05$) across all the samples; repeatability denotes the number of attributes for which there is no significant difference ($p < 0.05$) across the four replicates for the same product. The ideal value for Total is 48. Overall, the panel performance was acceptable, as seven out of eleven panellists were successful at discriminating attributes. Furthermore, panellists showed good repeatability by rating more than half of attributes consistently throughout the evaluations. Although panellist 3 showed lowest discrimination power amongst attributes, their repeatability was decent and hence included in the data analysis.

*Table 6: Summary of panellist performance, discrimination power and repeatability determined from an ANOVA model of the sensory data obtained for samples. (n= 12 samples x 4 replicates x 11 panellists)*

| Panellist | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Discrimination | 16 | 12 | 7 | 14 | 10 | 14 | 13 | 14 | 11 | 13 | 11 |
| Repeatability | 18 | 20 | 19 | 16 | 20 | 19 | 16 | 21 | 21 | 15 | 21 |
| Total[a] | 34 | 32 | 26 | 30 | 30 | 33 | 29 | 35 | 32 | 28 | 32 |

[a]The ideal total value is **48**.

Attributes *other aroma*, *other flavour*, and *other aftertaste/afterfeel* were excluded from panel evaluation analysis.

**Table 7** shows the F ratios and significance of the effects of sample (fixed), panellist (random) and replicate (random). A significant effect of sample was observed in all attributes besides *metallic AT*, suggesting that this attribute was not an important discriminator. Overall, the panel was able to discriminate the intrinsic sensory differences among the papaya samples. There were significant differences among all panellists for each attribute, indicating that panellists were using attributes differently which is typical of sensory data. For most of the attributes, there were no significant differences in how they were rated between each replicate, which suggests that the panellists rated most attributes consistently throughout the replicates. Only *citrus AR*, *dissolving TX*, and *bitter AT* was significantly different, which could be due to inconsistent use of this attribute by the panellists across different sessions or inconsistency in the different papaya samples used.

*Table 7: F-ratios and significance for effects of 12 samples, panellist and replicate (4 replicates x 11 panellists)*

| Sensory attribute | Sample | Panellist | Replicate |
|---|---|---|---|
| *aroma intensity AR* | 28*** | 9*** | 1 |
| *sweet fruit AR* | 24*** | 9*** | 0 ns |
| *musty - off note AR* | 3** | 18*** | 2 ns |
| *fishy AR* | 7*** | 10*** | 1 ns |
| *citrus AR* | 29*** | 6*** | 3* |
| *floral AR* | 31*** | 5*** | 0 ns |
| *root vegetable AR* | 5*** | 26*** | 1 ns |
| *green AR* | 3* | 21*** | 0 ns |
| *resistance TX* | 29*** | 8*** | 1 ns |
| *velvety TX* | 2 ns | 10*** | 1 ns |
| *juiciness TX* | 38*** | 16*** | 1 ns |
| *dissolving TX* | 14*** | 8*** | 3* |
| *fibrous TX* | 10*** | 3* | 2 |
| *flavour intensity FL* | 19*** | 11*** | 0 ns |
| *sweetness FL* | 14*** | 5*** | 0 ns |
| *bitterness FL* | 4*** | 30*** | 1 ns |
| *musty FL* | 8*** | 22*** | 1 ns |
| *floral FL* | 14*** | 11*** | 2 ns |
| *tropical fruit FL* | 16*** | 23*** | 1 ns |
| *root vegetable FL* | 7*** | 25*** | 1 ns |
| *bitter AT* | 5*** | 29*** | 3* |
| *sweet AT* | 11*** | 39*** | 2 ns |
| *metallic AT* | 1 ns | 77*** | 0 ns |
| *prickly AT* | 1 ns | 92*** | 0 ns |

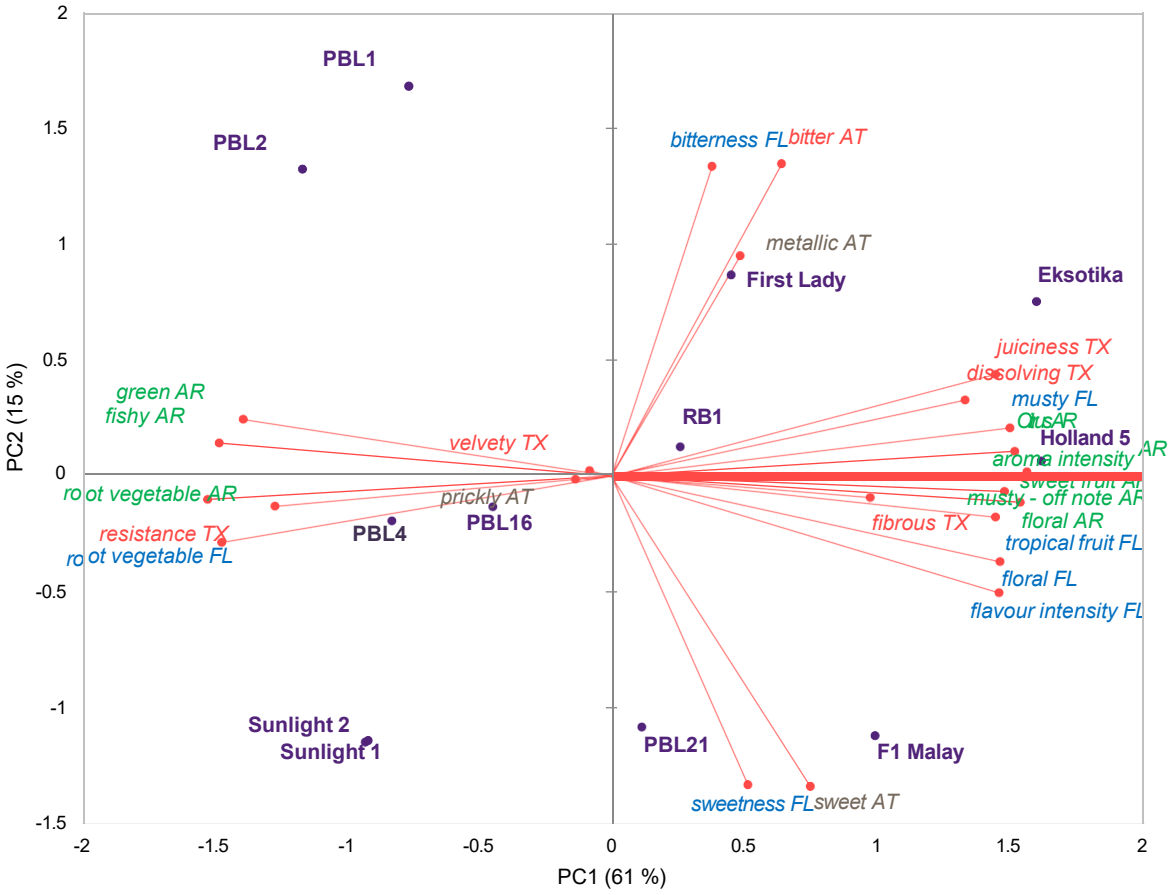
Significant F-ratios are indicated by * ($p < 0.05$), ** ($p < 0.01$), ***($p < 0.001$) and ns: not significant ($p > 0.05$).

AR, aroma attributes; TX, texture attributes; FL, flavour attributes; AT, aftertaste attributes.

## Sensory profiles of 12 papaya varieties evaluated by descriptive sensory analysis

A PCA bi-plot of the sensory scores (n=12) is given in **Figure 3**. Within the first two principal components of the PCA, 67% of the variation was explained. Although the third PC was also explored, it represented less than 10% of the variation in the dataset and therefore was not considered important for interpretation. Sample 'Eksotika', 'Holland 5', and F1 Malay were similar to each other having high scores for *aroma intensity,* with *citrus, sweet fruit, musty off-note* and *floral* being the dominant aromas. These samples also scored high in *flavour intensity*, being high *floral, tropical fruit, and musty* flavour. In terms of textural properties, those three papaya varieties scored highest for *juiciness, fibrous* and *dissolving*. Papaya varieties RB1, Holland 5, PBL21 and F1 Malay scored highest for *sweetness* and *sweet* aftertaste. Samples PBL16, PBL1, PBL3, PBL4, and Sunlight 2 showed highest scores for *fishy* and *green* aroma. Based on the Pearson's correlation all aroma attributes were strongly correlated, indicating that flavour, texture and aftertaste sensory attributes were more differentiating factors among the papaya samples than the aroma attributes. It was identified that juiciness and *dissolving* texture was positively correlated ($r > 0.696$) with *aroma intensity* and pleasant aromas including *sweet fruit*, *citrus* and *floral*, and *flavour intensity*, whereas negative correlations ($r < -0.762$) with *root vegetable*, *fishy*, and *green* aromas were identified.

*Figure 3: PCA bi-plot of the sensory descriptive data for 12 papaya samples (n= 4 replicates x 11 panellists)*



# Conclusion

A descriptive analysis sensory study was successfully carried out for the February 2024 harvest. Twelve papaya samples were evaluated by conventional descriptive profiling with a trained sensory panel. Among the twelve papaya samples, there were quite some differences perceived by the trained panel. In particular, papaya samples 'Eksotika', 'Holland 5', and F1 Malay had stronger *aroma* and *flavour intensity*, and highest scores for *sweet fruit* aroma, as well as showed highest *juiciness* and *dissolving* scores for texture compared to the other samples. The samples PBL1 and 'Eksotika' were characteristic for their *bitter* taste and aftertaste, while, PBL16, PBL1, PBL3, PBL4, and 'Sunlight 2' scored highest for *fishy* aroma. Overall, the papaya varieties were distinguishable based on aroma, flavour, texture and aftertaste of which some showed more favourable sensory attributes such as *juiciness* texture, *sweet* taste and *sweet fruit* aromas (detected in PBL21, Eksotika, F1 Malay, RB1, and Holland 5) and other less favourable profiles based on their increased score for *fishy* aroma (detected in PBL16, PBL1, PBL3, PBL4, and Sunlight 2).

# Appendices

*Appendix 1: Photographs of papaya half samples (n=12) for formal testing*

*Appendix 2: Method of cutting papaya samples*

Step 1: Wash papaya with water

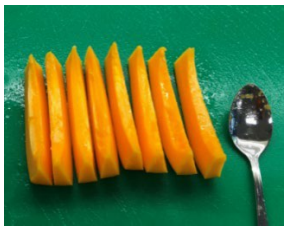
Step 2: Cut papaya in half

Step 3: Remove seeds from papaya half

Step 4: Cut papaya half into quarters

Step 5: Remove top and bottom wedge

Step 6: Cut quarters into slivers



Step 7: Remove skin off slivers

Step 8: Cut slivers into cubes

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