Horticulture Innovation Australia

Final Report

Objective Colour Assessment Options for the Dried Grape Industry

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Summary

The best quality dried grapes are plump, golden and uniform throughout the batch. Light coloured fruit are worth significantly more than dark fruit, so the colour grade of fruit directly affects how much the grower is paid. Currently, experienced assessors grade dried grapes using defined criteria. However, the subjective nature of such assessments leads to variation and, therefore, disputes.

This project has developed and tested a number of methods for objectively measuring the colour of dried grapes. Initially, methods of colour assessment for a wide variety of food items were reviewed. Samples of dried grapes were then grouped using a nine-band colour scale. Each standard colour could be defined and colour space calculated from photographs imported into Adobe Photoshop. This was correlated with measurements taken using a Minolta chroma-meter as well as spectral absorbance recorded with a scanning spectrophotometer. This allowed determination of critical limits for light vs brown fruit, and calculation of average colour for remaining fruit within a batch.

A number of different methods for grading fruit were then tested. Discriminating parameters were used to try to divide fruit samples into the same or similar grades to those assigned subjectively by the processors. Samples were divided into the different colour bands by visual sorting, analysis of bulk photographs in Photoshop, or machine vision analysis of images taken by a flatbed scanner.

None of the methods resulted in all samples being given the same grade as the one previously allocated by subjective inspection. However, it was possible to obtain reasonable correlations between assigned and calculated grades. It seems likely that sample size and collection are key to allocating grades consistently. Moreover, the results confirmed that subjective grading inevitably delivers variable outcomes.

Analysis of bulk images was difficult due to uneven lighting of fruit within the sample. In this trial, photographs of dried grapes within a bin could not be used to consistently allocate crown grade, although this method could discriminate between "light" and "brown" fruit.

The flatbed scanner provided images that could be readily separated from the background and analysed using machine vision systems. Combining delimiting values for hue and saturation provided the best way of grading dried grapes. This method appeared to have excellent promise, although more work is needed to ensure that the delimiters used are appropriate and provide consistent results.

Whichever method is used, the consistency of grading could be improved by simplifying the existing system. Nine different grades are currently in use. However, only 4–5 different rates are paid by processors. Grading fruit according to end use could reduce the number of grades to approximately four. Combined with objective colour measurement, this could reduce or eliminate disputes between growers and processors.

In addition, preliminary tests examined the use of near–infrared (NIR) to measure moisture content of dried grapes. A Felix F-750 was calibrated using oven-dried samples. Measured readings were within ±0.6% of actual values. This is in contrast to the current system, which provided readings within ±1.4% of actual value. While more work is needed, NIR may provide a fast and accurate method to measure moisture content of dried grapes.

Keywords

Sultana, dried, grape, raisin, colour, vision, moisture, drying, near-infra-red, spectra, quality, grading

Introduction

High quality dried grapes should be golden, plump and uniform throughout the batch. The relatively light and even colour of Australian dried grapes, due to our drying techniques, is one of the key quality attributes that differentiates them in domestic and the international markets. Light coloured fruit are worth significantly more than dark fruit, particularly in export markets. The colour grade of fruit therefore directly affects how much the grower is paid.

In other industries, harvested fruit is graded and packed soon after delivery. The grower can then be paid according to the number of fruit in each class – determined by factors such as size, defects, dry matter or firmness. However, in the case of dried vine fruit, several months can pass between receival and when the product is processed and packed. It would be unreasonable to expect growers to wait months to be paid for their fruit. Moreover, stored product will continue to darken, especially under ambient conditions.

Fruit therefore needs to be assessed on receival so that the grower can be paid appropriately. With large volumes of fruit being delivered during a relatively short harvest season, assessment needs to be fast and consistent. Experienced assessors currently evaluate dried grape colour subjectively on delivery. However, as colour and consistency determine grade, and grade determines price, differences in judgment almost inevitably lead to disputes between growers and processors.

Objective colour measurement has therefore long been an industry priority. Research nearly 15 years ago proposed the use of near infrared spectroscopy to measure dried grape colour. However, advances in technology mean that a range of different techniques are now available, and could be suitable for measuring dried grape colour.

The issue is made more difficult by the complex system of grading that is currently used. Fruit is currently graded as either "light" or "dark" according to the base colour of the majority of fruit, and then allocated a crown grade, nominally from 1 to 7 but more usually between 3 and 5 (Table 1).

Table 1 - Dried grape grades

Grade		Base colour of fruit	Colour of remaining fruit
LIGHT	6 crown light	Bold, bright amber colour	5% dark berries
	5 crown light	Light amber colour	10% dark berries
	4 crown light	Average amber colour	15% dark berries
	3 crown light	Amber to light brown	20% dark berries
	2 crown light / standard	Light brown	50% dark berries
DARK	5 crown brown	Dark amber colour	10% dark brown berries
	4 crown brown	Dark amber to brown	15% dark brown berries
	3 crown brown	Uniform brown	20% dark brown berries
	2 crown brown / standard	Uniform dark brown	N/A

The combination of both '"base colour" and "number of dark berries" makes it particularly difficult to grade fruit consistently, despite grade samples being selected and retained for comparison at the start of the season.

This project has reviewed different ways of measuring the colour of dried grapes, and tested some of these methods using graded samples supplied by the major processors. The objective has been to determine a test and set of criteria that correlate with subjective assessment. Methods and criteria have been assessed manually, using existing image analysis software. If effective, this could later be developed into a fast, automated system using appropriate equipment and software.

As an additional activity, the project team has conducted an initial assessment of the use of NIR (near-infra-red) technology to measure moisture content in dried grapes. This method could potentially provide a much faster measurement of internal moisture than current, manual techniques. As dried grapes must be supplied within a relatively small moisture content range, a method that allows both growers and processors to quickly assess drying rates and suitability for storage and processing would be of great value to the industry.

Methodology

Task 1 – Identify and critique the equipment and technology available to measure dried vine fruit colour.

An extensive review was conducted of ways of measuring colour of fresh products. This included discussion of the different technologies available (colorimetry, spectrophotometry, photography) and the advantages and disadvantages of each method.

The application of each of these technologies to the specific needs of the dried grape industry was then assessed. While the literature revealed little information about dried grapes specifically, a number of machine vision systems have been used to examine other mixed colour samples. Published image analysis methods included:

- evaluating the ratios of different ingredients used as pizza toppings
- calculating the percentage of chocolate chips in cookies
- detecting uneven browning during cooking of potato crisps
- quantifying ripening of bananas using the appearance of black spotting
- measurement of wheat grain size and colour
- diagnosis of disease by analysing the colour of a test strip or photograph with a smartphone

The full literature review is included as **Attachment 1** to this report.

Task 2 – Prioritise equipment / method that could be used to non-destructively measure dried grape colour.

A key part of this project has involved formation of a project reference group with members of the dried vine fruit industry. This included growers, processors, Dried Fruit Australia (DFA) staff and a HIA representative.

Two meetings have been held with this group in Mildura. At the meeting in February a presentation was given outlining the project, describing what is meant by colour and providing the results of previous work conducted by AHR on colour analysis of grapes and other horticultural products. The meeting in March included presentation of the results of the literature review conducted in Task 1, and discussion of the next steps.

Minutes from these meetings are included as **Attachment 2** to this report, as is the Powerpoint presentation of the literature review results.

The issues relating to colour measurement were also discussed individually with growers and processors at a series of site visits conducted in February and March 2016. Discussion included the process flow used at Sunbeam and Australian Premium Dried Fruits in terms of fruit delivery, testing, grading, storage, processing and packing. This clarified how any objective colour measurement would need to be implemented on-farm or at the processor in order to meet industry needs as well as be practical and effective.

Task 3 –Test feasibility of using recommended equipment / method for measuring dried grape colour

Fruit samples

During site visits in both February and March a large number of dried grape samples were collected for testing methods of objective colour assessment. Experienced fruit assessors at Sunbeam and Australian Premium Dried Fruits graded all samples using standards they retain on-site. The grade, source and in some cases moisture content were recorded for each sample.

Samples were photographed in three different ways:

1. Sample was placed in a small dish, with fruit at least three layers deep. A white reference + label was included in each photograph. Each shot included the whole tray on a black background, to act as a black reference. Photographs were taken using a Canon EOS 40D SLR camera mounted onto a frame in the centre of 4 large photolamps (125W 5500K natural daylight).

2. Sample was spread over the top of a standard flatbed scanner. A white-grey-black balance standard was included in each scan.

3. Sample was spread over the top of a standard flatbed scanner and topped with a piece of black velvet. A white-grey-black balance standard was included in each scan.

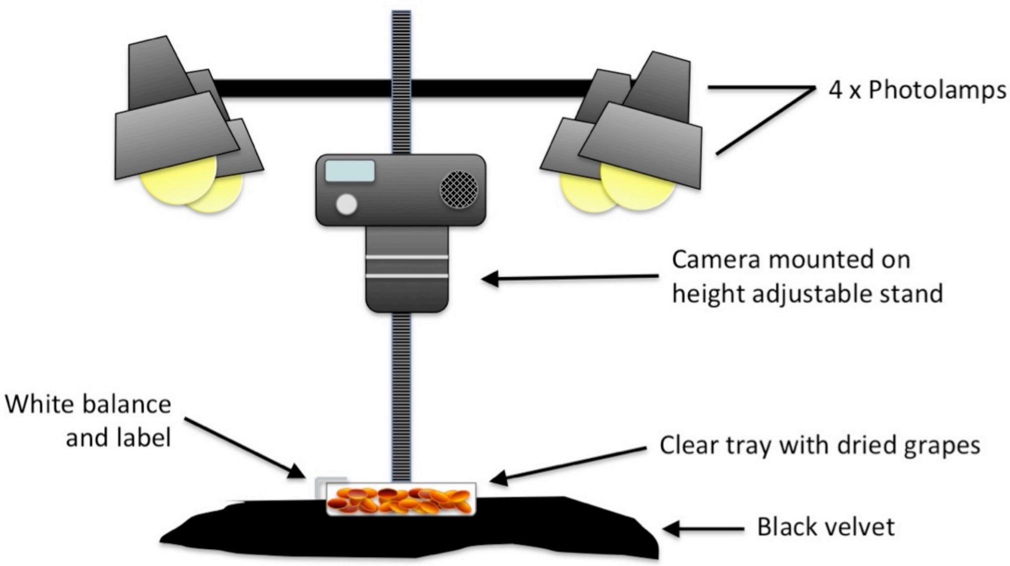

Figure 1. Photographic setup for recording dried grape samples

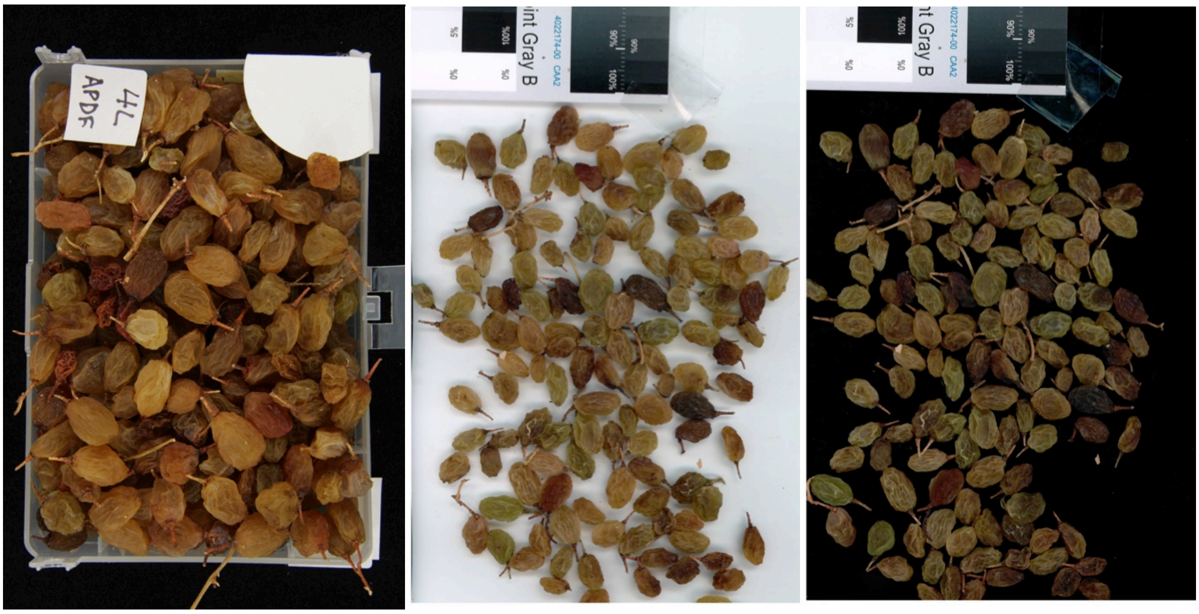

Figure 2. Images taken with a camera (left) or with a flatbed scanner (right). All samples were graded 4 crown light.

Standard dried grape colours

A series of 'standard' colours were developed. Dried grapes were visually divided into nine different colour types, ranging from 'greenish' and 'gold' to 'dark brown' and blackish' (Figure 3).

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Greenish	Gold	Lt amber	Amber	Dk amber	Lt brown	Brown	Dk brown	Blackish

Figure 3. Colour grades of dried grapes

Ten dried grapes visually judged to be close colour within each cohort were measured using a Minolta chromameter, with values output as L*, a* and b*. Each group was then photographed on a black background as previously described. A piece of white filter paper was included in each photograph to provide a white reference.

Photographs were analysed using Adobe Photoshop. After white and black balance adjustment, each dried grape was individually selected and central area averaged. The colour of this area was recorded as R, G, B as well as the Adobe values for Hue, L, a and b.

Setting delimiters and sorting criteria

In discussion with the industry it was agreed that berries darker than 8 (dark brown) would be considered dark fruit. For grading purposes, samples with base colour (not counting dark fruit) between 2 and 5 would be considered light; samples with base colour of 6 or higher would be considered brown. These values could therefore be used to set delimiting values for objective colour sorting of dried grapes.

To test this method, a number of samples of dried grapes were visually sorted into groups corresponding with the standard colour swatches. This was done inside a white cabinet illuminated with a daylight fluorescent tube.

Figure 4. Sorting groups of dried grapes into visual colour bands.

The percentage of dried grapes corresponding to each colour was calculated and compared with the descriptors used in the crown grade system. While a number of the samples corresponded with the grade descriptors, there were also some significant discrepancies.

This raised the question of what is the key determinant of grade – base colour or dark berries?

As the dried grapes are colour sorted as they move through the processing line, it seems likely that the factor which will most determine value is the number of light fruit. That is, fruit which have a score of 5 or less against the colour swatches. If the majority of these fruit are Light amber (3) rather than Dark amber (5), then this may add additional value to the batch.

If less than 70% of fruit are light coloured (APDF pers com), it will not be worthwhile to colour grade the batch. In this case, the variability within the sample may determine value, with more homogenous batches valued more highly. Based on these principles, a logic flow for grading was developed for further testing.

Grading using photographs

Grading using photographs of whole batches would be the easiest method to implement within existing receival processes. A system could be envisaged where a frame incorporating standard lighting and a digital camera (ipad or smartphone) would be simply placed over a bin of fruit. The photograph could be taken and analysed by on-board software, which would output a grade for the fruit.

To test whether this was feasible, photographs of the trays of dried grapes were analysed using Photoshop. Photographs were first adjusted using black and white balances. The centres of individual fruit within each tray were then selected and averaged using the "blur" tool. The Hue angle and L value of each berry was then recorded using the "colour picker" tool. Approximately 80–90 individual berries per sample were measured in this way. In addition, the average colour of whole trays, and of whole trays with dark areas removed, was also recorded.

A minimum of three samples per grade (3, 4 and 5 light and 3, 4 and 5 brown) were analysed using this method.

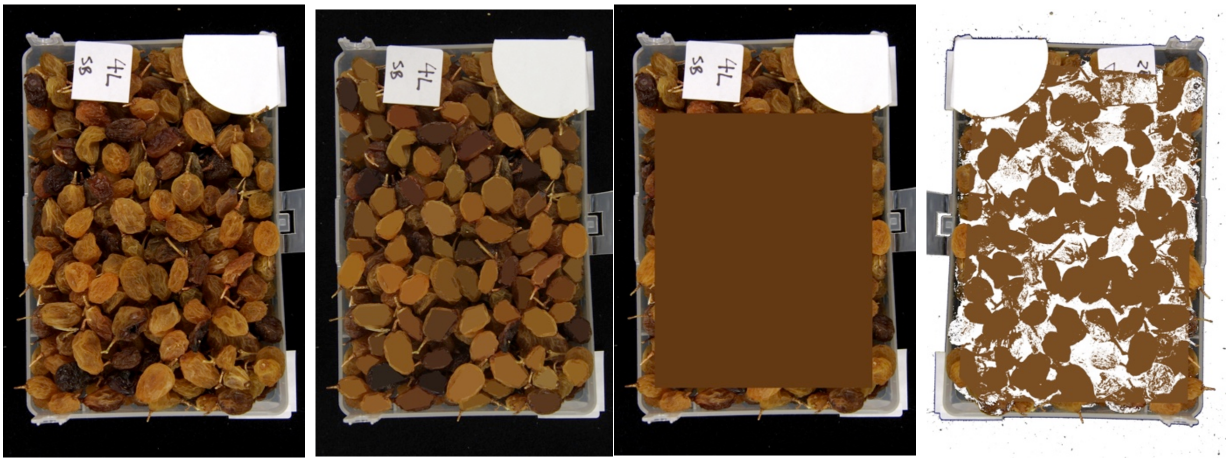

Figure 5. Image analysis using Photoshop. Original photograph shown at left. The colour of individual berries was measured by selecting the centre of each and averaging using the "blur" tool. The average colour of the whole image, and of the image with dark areas removed (right) was also assessed. Hue and L values were recorded for each area using the "colour picker" tool.

The results were assessed using the logic flow system for recording the percentage of dark fruit, the average colour of the remaining fruit, and the colour variability of non-dark fruit.

Grading using scanned images

Scanned images have the advantage that dried grapes can be clearly separated from each other, allowing easier analysis of colour. Scanners are fast and readily available, however this does mean that sampling would not take place at the bin itself, but at a central, specifically setup grading area.

Images of dried grapes scanned against white and black backgrounds were analysed. Images were initially smoothed to remove the effects of wrinkles. Unwanted pixels (dried grape stems) and blemishes, as well as the background were removed from the image using masking tools (Otsu's method) and the image converted to hue saturation values (HSV, a colour system commonly applied in computer vision technologies).

A threshold was applied on hue and saturation values using the nine standard colour grades as fixed "centroids". The distance of each pixel from these centroids was calculated using squared Euclidean distance and the dried grapes graded according to the proportion of each colour in the sample.

Grading using a spectrophotometer

The samples of ten dried grapes per colour grade were not only scanned and photographed, but also analysed using a scanning spectrophotometer. This activity was conducted by Stuart Rumble of Quark Photonics. The scans produced were analysed to determine whether this method could differentiate between the different colour standards of dried grapes, as well as to determine which wavelength/s would be most appropriate for this purpose.

NOTE: This activity is ongoing, as not all data has been analysed. However, trial methods and results to date are included as **Attachment 3** to this report.

Task XX – Developing a fast and accurate method for measuring moisture content of dried grapes.

This activity was not included in the tender or project plan, but arose fortuitously during other activities. The Felix F-750 Produce Quality Meter is a commercially available tool used to non-destructively measure sugars, dry matter, and other quality attributes of fresh fruit. Although mainly focussed on near-infrared, it also measures visible colour.

The F-750 was used to scan 30 samples of dried grapes with different moisture contents. In some cases the moisture content measured by Sunbeam or APDF was supplied with the sample. Samples were loaded into a small jar to a depth of approximately 50mm. The spectra recorded by the F-750 was sent to Central Queensland University for analysis.

All samples were then oven dried until they were no longer losing weight. The percentage moisture content of each sample was correlated with the spectra to evaluate the accuracy of this method.

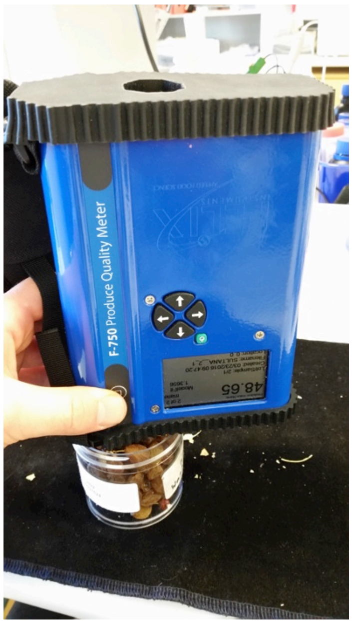

Figure 6. Using the Felix F-750 to analyse grape samples

Outputs

Reports

The literature review and summary of results has been circulated among the project reference group as well as to other interested parties.

The final results will be printed and provided to the reference group, including Sunbeam and Australian Premium Dried Fruits, who are likely to be the main users of these results.

An article on the work will be submitted to ”The Vine” magazine for publication and wide distribution among members.

Presentations

Two presentations have been given to the project reference group. These have focused on colour generally, including the results of the literature review and some initial results from the trials. A final presentation is planned for August 2016, when a number of the group members return from leave and all results are complete.

Tools

Several different tools have been tested for objectively measuring the colour of dried grapes. These are still in progress at the current time. However, software is being developed through the Central Queensland University. Results so far are extremely promising, with this method expected to provide the basis for an effective technique.

The results using the Felix F-750 to test moisture content are also extremely promising. However, further calibration of the equipment is required to ensure results are equivalent to, or better than, existing techniques.

Outcomes

Standard colour of dried grapes

Measurement of the nine colour groups of dried grapes, each containing 10 fruit, was consistent whether measured with the Minolta chromameter or Photoshop. Although values differed, changes between the different colours were closely correlated (Figure 7). Moreover, variability within each cohort was relatively small, indicating that visual sorting had grouped the fruit correctly.

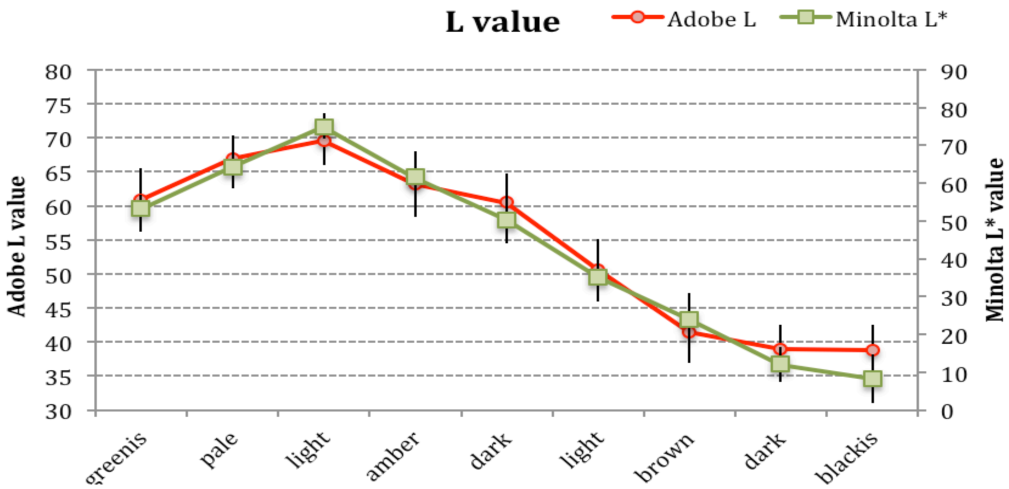

Figure 7. L values for different colour grades of dried grapes, calculated from images with Adobe Photoshop or analysed using a Minolta chromameter. Bars indicate the standard deviation of each mean value (n=10)

Mean values could be calculated for each cohort, and used to turn the different standard colours into swatches with known values.

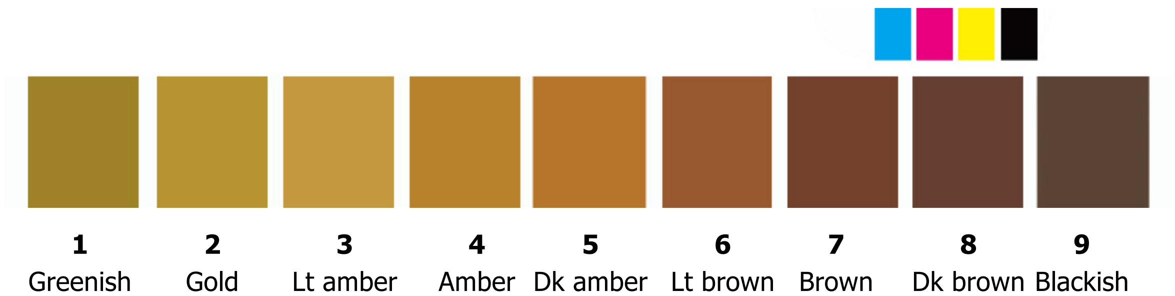

Figure 8. Colour swatches, based on mean colour values for different colours of dried grapes. A CMYK reference is included for printing purposes.

Values for a and b can be integrated by calculating the Hue angle. This provided excellent discrimination between the different dried grape colours.

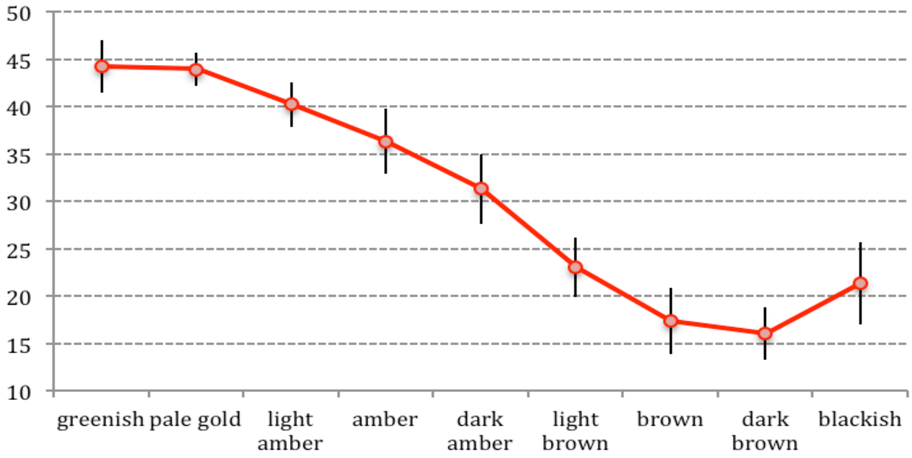

Figure 9. Hue angle values of different colours of dried grapes. Bars indicate the standard deviation of each mean value (n=10)

Setting delimiters and sorting criteria

When samples were fully sorted into different colours, using the standard swatches as references, it became apparent that significant variation can occur between "visual" grade and "measured" grade. Of the 17 samples examined, six would have been given a different grade based on the detailed sorting of the fruit (Table 2).

Table 2. Grading of dried grapes by processors compared to using colour sorting of the sample

Sample	Base colour	Dark berries (%)	Processor grade	Alternate grade?
3L-_sample 1	Light amber	6.3	3L	5L
3L_sample 2	⅔ Gold ⅓ Light brown	3.9	3L	3L
3L_sample 3	Light amber	14.3	3L	4L
4L_sample 1	Gold	9.2	4L	4L
4L_sample 2	Amber	2.9	4L	4L
4L_sample 3	Amber	1.1	4L	4L
5L_sample 1	Gold	6	5L	5L
5L_sample 2	Gold	6.5	5L	5L
5L_sample 3	Light amber	0	5L	5L
3B_sample 1	⅓ Amber ⅔ Brown	97.4	3B	3B
3B_sample 2	Brown	63.3	3B	4B
4B_sample 1	Light brown	14.4	4B	4B

4B_sample 2	Light brown	0	4B	4B
4B_sample3	Dark amber	5.9	4B	3L
5B_sample 1	Dark amber	9.6	5B	5B
5B_sample 2	Light brown	5.7	5B	4B
5B_sample 3	Dark amber	11.1	5B	4B

One of the reasons grading is so difficult is that the industry grades define both a base colour, and the percentage dark fruit. If the base colour is light but the percentage of dark berries is high the sample cannot be described using the existing system.

A process flow for a grading system was therefore proposed. Actual values may need to be adjusted to ensure grading corresponds with visual assessments:

- Count the no. of dark fruit; if >30% have H°<27 then sample=brown else sample=light
- If light, count the no. brown fruit. If >30% have H°<30 then grade=3
    - Exclude berries with H°>42 or H°<20
    - Calculate average of remaining fruit.
        - If H°>37 then grade=5
        - If H°=32−37 then grade=4
        - If H°<37 then grade=3
- If brown
    - Calculate the average of all fruit.
        - If H°>25 then grade=5
        - If H°=20−25 then grade=4
        - If H°<20 then grade=3

Grading using photographs

Hue angle proved a better method of discriminating between samples than L value. It was also noticeable that all L values were lower i.e. fruit were darker, when fruit was photographed as a mass compared to when fruit was separated. This is likely due to shadowing, despite strong and multidirectional light being directed at the samples.

Calculating the percentage of individual berries with H°<27 proved an effective way to discriminate between light and brown fruit samples. This resulted in a grade change for only one sample from the 12 analysed.

Simply measuring the average H° of the whole tray could also quickly and easily discriminate between light and dark samples. This method is considerably simpler than measuring individual berries, but did result in greater overlap between samples.

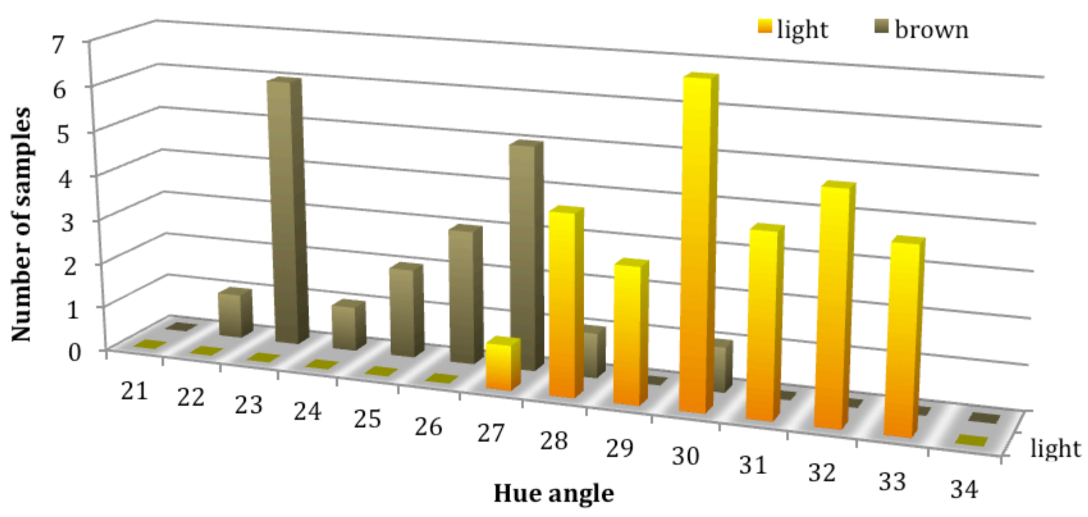

Figure 10. Mean hue angle of trays of dried grapes graded as light (n=28) or brown (n=21).

However, it was more difficult to distinguish between crown grades. Methods tested as ways of separating the crown grades within the light fruit category included:

- The percentage of brown berries (H°<30)
- Average H° of 80 individual berries
- Average H° of 80 individual berries, berries with H°<27 removed from the analysis
- Average H° of light parts of the image (sections with H°<27, L<10 were removed from image)
- Average H° of whole tray

In all cases, values were similar across the six different samples of crown grades.

One way to potentially distinguish between crown grades is by examining how closely values are clustered around the median. For example, it can be seen in Figure 11 that the 4 crown light sample is more homogeneous than the 3 crown light sample.

Figure 11. Range of Hue angle values within two dried grape samples. The 3 crown light sample shows a wide range of different values, whereas most values are within a small range in the in the 4 crown light sample.

Grading using scanned images

Hue proved a better delimiter for defining differences in colour between batches of dried grapes than other values tested. However, the best results were gained when both hue and saturation were used to define colour.

Table 3. Grading of dried grape samples with a machine vision system using hue, saturation or hue + saturation as delimiting values. Measured grade was either the same, or different to, the grade allocated subjectively.

	Saturation only		**Hue only**		**Hue and saturation**	
	Same	*Different*	*Same*	*Different*	*Same*	*Different*
Light	7	11	12	6	12	6
Brown	14	4	5	13	9	9

Grading using a spectrophotometer

Grapes with a green tinge could be very clearly differentiated from other fruit, doe to their much higher absorbance between 650-700nm wavelength. This wavelength could discriminate very clearly between dried grape colours 2–5 and dried grape colours 1, 6–9. The results indicate that the spectra of dried grapes could be used to discriminate between different colours at a range of values. However, it should be noted that the results were very variable between individual fruit, so further calibration would be necessary to confirm the consistency of results.

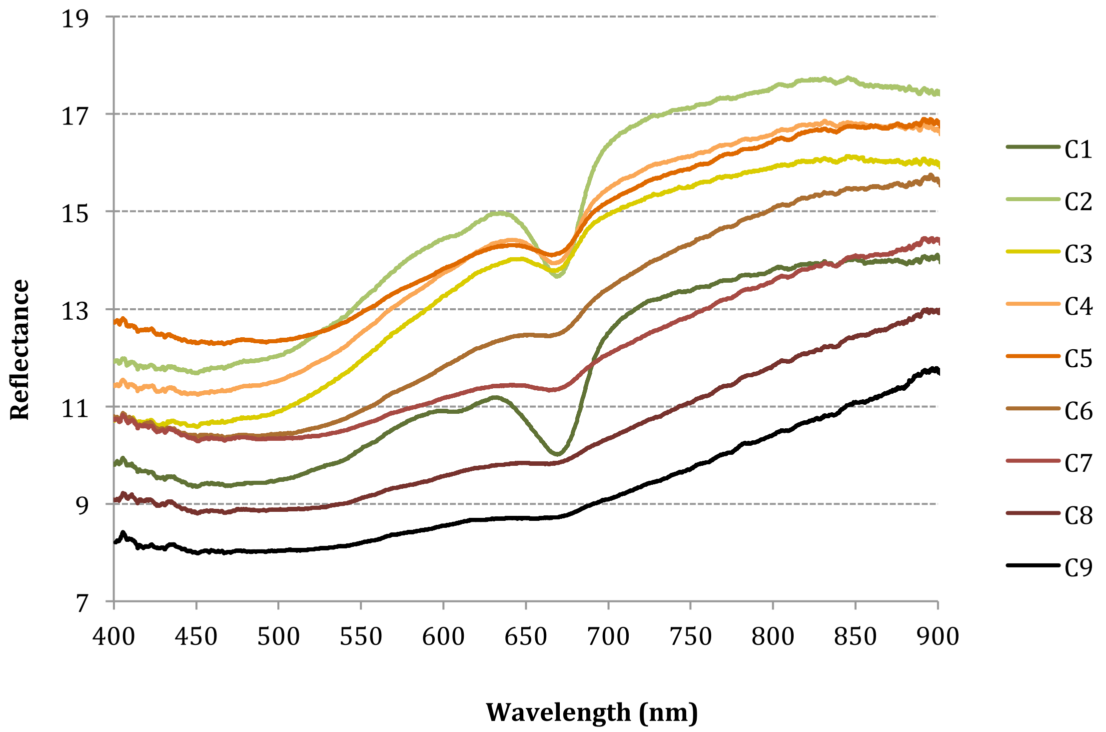

Figure 12. Spectra of dried grapes ranging from standard colour 1 to 9. Lines calculated as mean values from 10 individual fruit.

Moisture content

Measurements of moisture content using the standard industry method were generally higher than results obtained by oven drying the samples. Moisture loss from the samples was surprisingly slow, and long oven drying times were needed before sample weight stabilised. It is possible that some additional metabolites were destroyed during this process. Despite this, differences in results ranged from -0.3% to +3.2% and averaged ±1.4%. This suggests the industry method may not always provide an accurate measure of moisture content of dried grapes.

Good correlations were obtained comparing the NIR method to the oven dried samples. Thirty samples were used to calibrate the machine, with a further 10 samples analysed using the method. The standard deviation of readings was ±0.6%. Results gained using the NIR were within ±1.0% of those from the oven drying method, with an average difference of 0.5%.

While more data is needed to ensure the machine is correctly calibrated, the results suggest that the Felix F-750 could be used to provide a fast and accurate method of measuring moisture content of dried grapes.

Evaluation and Discussion

The project has successfully defined colour groupings for dried grapes and tested a number of methods for measuring colour.

In summary:

- Dried grapes can be divided roughly into nine distinct colour groupings, each of which can be given a numerical value using existing colour space systems (Lab, HSV etc)
- Defining colour of individual berries in a bulk sample, as with a photograph of a bin of fruit, is problematic due to uneven lighting of the sample
- Different coloured fruit can be discriminated using their spectra, however it is unclear how a bulk sample could be assessed using this technology
- Images taken with a bench-top scanner allowed relatively easy discrimination of individual fruit from their surroundings using image analysis and masking tools
- Images taken using a bench-top scanner could be readily analysed using both hue and saturation and allocated a grade accordingly

Grading samples based on the current system has proven very challenging. None of the methods tested resulted in grades that were exactly the same as those which had been allocated subjectively by professional grape assessors. Even sorting a sample of grapes into different colour bands, then counting the number in each sample did not result in the same colour grades as had been allocated. However, there was a reasonable correlation between subjectively and objectively assigned grades for the majority of samples.

Moreover, some of the photographs / scans used do not – on close visual assessment – appear to be typical examples of the subjectively allocated grade. It is possible that the composition of the sample used for photography was not typical of the far larger volume contained in a bin of fruit. Sample size and selection may therefore be important in ensuring that grades are allocated consistently for each batch.

One way to reduce variability would be to simplify the grading system. The current system provides a total of nine different grades according to both the number of "dark" berries and the "base colour" of the remaining fruit. However, both of the major processors pay the same amounts for 2–3 different grades.

The reason for grading should therefore be considered. Grading occurs because light coloured ruit are worth more in certain markets. However, if less than 30% of fruit are light, then the batch is not worth sorting into light and brown. An additional consideration is that, if a batch of fruit is evenly coloured, less sorting is needed during processing to produce a consistent product.

It seems possible that the grading system could be simplified to more closely reflect commercial considerations. However, any new system of grading would need to be developed in partnership with both growers and processors.

Results from the preliminary work examining whether NIR could be used to rapidly measure moisture content of dried grapes are extremely promising. Clearly this method needs more extensive testing to develop an accurate calibration model for the Felix F-750 device. However, this could significantly reduce the labour and time required to measure moisture content, as well as possibly providing a more accurate measurement. Such a method would help growers optimise moisture content in harvested and dried grapes, as well as reduce costs for processors.

Recommendations

A number of activities still need to be completed. These include:

- Final assessment of different methods of measuring dried grape colour, including the promising scan method
- Presentation of results to industry
- Publication of results in the industry journal

Additional recommendations are likely once these activities have been completed and the best options discussed and prioritised with industry.

However, it is strongly recommended that work developing and objective colour measurement method for dried grapes continue. The trials have clearly illustrated that subjective grading of dried grapes regularly results in discrepancies between samples. There is a clear and urgent need for a more objective method that will meet the needs of both growers and processors.

It is also recommended that the new method developed should not exactly replicate the current system, but simplify grading in line with commercial uses of the end product. The complexity of the current system makes it difficult to implement consistently. Moreover, as prices are the same or similar for some different grades, this appears to add complications for no gain to either grower or processor.

Any change in the number and scope of grades must occur with the full agreement of industry. However, based on use patterns, it may be possible to reduce the number of grades to as few as four; Gold, Export, Retail, and Bakery. This could perhaps be a starting point for discussion:

1. Gold – less than 20% dark fruit, minimal sorting needed (equivalent to 5 crown light)
2. Export – less than 30% dark fruit, worthwhile to sort (equivalent to 4 crown light)
3. Retail – not worth sorting, but attractive in appearance (approximately equivalent to 3 crown light or 4–5 crown brown)
4. Bakery – not worth sorting, highly variable or very dark colour (equivalent to 3 crown brown)

The final recommendation is for continued development of new ways to measure moisture content of dried grapes. Drying fruit to the correct moisture content can help growers are to maximise their yield, and therefore returns. However, it is also critical for good postharvest quality and storability of the product. The current system is labour intensive, time consuming and may not be providing sufficiently accurate results. It cannot be done on farm, which limits how often measurements can be taken during the drying process. Developing fast and accurate methods for both growers and processors to measure moisture content would be a major beneift to the industry.

Many other industries also need to measure dry matter / moisture content of foods quickly and accurately. As well as conducting further testing and calibration of the Felix F-750 NIR device, it is therefore recommended to review methods used in industries such as grains, avocado, and food processing.

Scientific Refereed Publications

A draft paper on machine vision grading of dried grapes has been prepared for publication by Hina Ajmal. Mr Ajmal is a student at Central Queensland University studying this issue under Prof. Kerry Wash. This is included as **Attachment 4** to this report.

Further publications from this work are likely, given the importance of the results obtained.

Intellectual Property/Commercialisation

No commercial IP generated

Acknowledgements

The project reference group has provided invaluable input into the project. This work could not have been conducted without the background information and input provided by involved growers and DFA staff. The project team would particularly like to thank the processors, who provided samples for assessment as well as access to facilities and open discussion of approaches to this issue. The reference group includes:

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Peter Jones grower

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Ivan Shaw grower

David Swain Sunbeam Foods

Glenn Shaw Sunbeam Foods

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Appendices

Attachment 1 – Literature review

Attachment 2 – Reference group meeting minutes and presentations

Attachment 3 – Experimental materials, methods and results to date

Attachment 4 – Draft paper for peer reviewed publication

DG15001 Objective colour assessment of dried grapes

Literature Review and Recommendations

Contents

Introduction

The best quality dried grapes are plump, golden and uniform throughout the batch. Light coloured fruit are worth significantly more than dark fruit, particularly in export markets. The colour grade of fruit therefore directly affects how much the grower is paid.

Newly dried grapes are usually mixed in colour when delivered in bins for processing (Figure 1). The two major Australian processors – Sunbeam and Australian Premium Dried Fruits (APDF) both have colour sorters that separate light and dark fruit during cleaning and packing. However, removing dark fruit from a batch inevitably also results in rejection of some light fruit. This fruit needs to be re-sorted – all processes that increase fruit damage. It is therefore not worthwhile to colour sort a batch of fruit unless it is predominantly light in colour.

Grade, and therefore also the price paid to the grower, is largely a function of the base colour of the batch ('light' or 'brown') and the percentage of dark fruit (crown grade). For example, the 2016 pricing schedule for growers ranges from $1,320 to $2,200/tonne, depending on crown grade as well as base colour. Such a large difference in price means that the grade allocated to

Figure 1 - Range of colours of sultanas within a batch

In other industries, harvested fruit is graded and packed soon after delivery. The grower can then be paid according to the number of fruit in each class – determined by factors such as size, defects, dry matter or firmness. However, in the case of dried vine fruit, several months can pass between receival and when the product is processed and packed. It would be unreasonable to expect growers to wait months to be paid for their fruit. Moreover, stored product will continue to darken, especially under ambient conditions.

Fruit therefore needs to be assessed on receival so that the grower can be paid appropriately. With large volumes of fruit being delivered during a relatively short harvest season, assessment needs to be fast and consistent. To reduce the potential for disputes, it also needs to be objective.

Grading fruit

To understand the way that dried vine fruit are currently tested and graded, it helps to understand something of the history of the Australian industry.

The Australian dried fruit industry was pioneered in the late 1800's in fruit growing areas close to the Murray River. It expanded rapidly and by the 1890's a chaotic 'system' had developed for processing and marketing. After 1915 the industry expanded further, with thousands of returned servicemen from World War I given land in recognition of their wartime service. The result was thousands of 'blockies' dispersed around newly opened farming areas around Mildura, Renmark, Merbein and Red Cliffs.

Even by 1895 it was realised that competition between growers and packers was significantly reducing prices. The isolation of the region and the need to collectively market dried grapes in distant markets led through various stages to the formation of the Australian Dried Fruit Association (ADFA).

The ADFA was responsible for all grading and classing of fruit. They also tested moisture content, and regulated the percentage of fruit allocated to export markets from each region. One of the key objects of the association was to ensure equality amongst growers, with standard, amortised payments for similar grade fruit[1]. This was achieved partly through development and regulation of the grading system.

Although the industry is now fully de-regulated, this grading system has remained virtually unchanged. The product specifications listed by the Victorian Dried Fruits Board were – until only a few years ago – regulated by the Dried Fruits Act of 1958 and enforced by classers employed by the Board[2]. Although the processors themselves now conduct the assessment (except where there is a dispute), the grades are virtually unchanged. These grades are summarised in Table 1.

Table 1 – Sultan as well as costsa grades

Grade		Base colour of fruit	Colour of remaining fruit
LIGHT	6CL	Bold, bright amber colour	5% dark berries
	5CL	Light amber colour	10% dark berries
	4CL	Average amber colour	15% dark berries
	3CL	Amber to light brown	20% dark berries
	2CL / standard	Light brown	50% dark berries
DARK	5CB	Dark amber colour	10% dark brown berries
	4CB	Dark amber to brown	15% dark brown berries
	3CB	Uniform brown	20% dark brown berries
	2CB / standard	Uniform dark brown	N/A

The current method of grading relies on a highly subjective assessment of colour. What constitutes 'light amber', 'average amber' or 'light brown' is determined by the assessor. While every effort is made to reduce variability using standardised lighting, retained samples and the experience of the operator, it is inevitable that disagreements will occur. When such disagreements can mean a difference in price of several hundred $ / tonne, there is a clear driver for a more objective method of assessment. For example, the price difference between fruit graded 4CL and 3CL is up to $375/tonne (APDF, 2016). In the case of fruit graded as 'light' or 'brown' there can be a price difference of $200 to $400/tonne (Sunbeam, 2016).

[1] Winterbottom DC. 1936. The origin and growth of the Australian dried fruits association. Dried Fruits News Oct. 1936
[2] Dried Fruits Regulations 1988, Version no. 011, Vic. Dried Fruits Board, inc. amendments 15 April 1998

The percentage of dark fruit can be estimated by separating a 100g sample into light and dark fruit. The fruit in each portion can then be either counted (Sunbeam) or weighed (APDF). However, such a process is highly time consuming. Percentages of dark fruit will also be assessed subjectively, based on the overall visual impact of the batch, especially during busy periods.

Grape colour

The colour of dried grapes is due to a combination of enzymatic and non-enzymatic processes.

- Enzymatic browning occurs when compartments inside the cells break-down, as occurs during the initial stages of drying. This allows the enzyme polyphenol oxidase (PPO) to contact phenolic compounds enclosed in the cell vacuoles. Such compounds are most plentiful in the grape skins and seeds[3]. High sugar concentrations – such as occur once grapes lose around 50% moisture – inhibit this reaction. As a result, rapid drying reduces development of brown colour[4].

- Non-enzymatic browning is caused by Maillard reactions. These occur when sugars break down, and are strongly time and temperature dependant. Unlike enzymatic browning, which occurs within days, non-enzymatic browning continues over several months. Maillard reactions not only produce dark coloured compounds but also flavours such as caramel and malt[5].

Maillard reactions are normally detected by formation of hydroxymethylfurfurals (HMF). It could be expected that dried grapes high in these compounds will also be strongly coloured. However, re-analysis of data presented by Sevik et al[6] shows no relationship between these values (Figure 2). This suggests that the colour of dried grapes is mainly the result of enzymatic browning.

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[3] Moskowitz A, Hrazdina G. 1981. Vacuolar contents of fruit epidermal cells from Vitis species. Plant Physiol. 68: 686-692
[4] Grncarevic M, Hawker JS. 1971. Browning of sultana grape berries during drying. J. Sci. Food. Agric. 22: 270-272
[5] Frank D. 2002. Investigation of the biochemical basis of browning during the storage of sultanas. PhD Thesis, Centre for Bioprocessing and Food Tech., Vic. Uni. Tech.
[6] Sevik R, Sen L, Nas S. 2014. Determination of color quality and HMF content of unprocessed sultanas obtained from different vineyards. Int J. Res. Ag. Food Sci. 2: 32-42

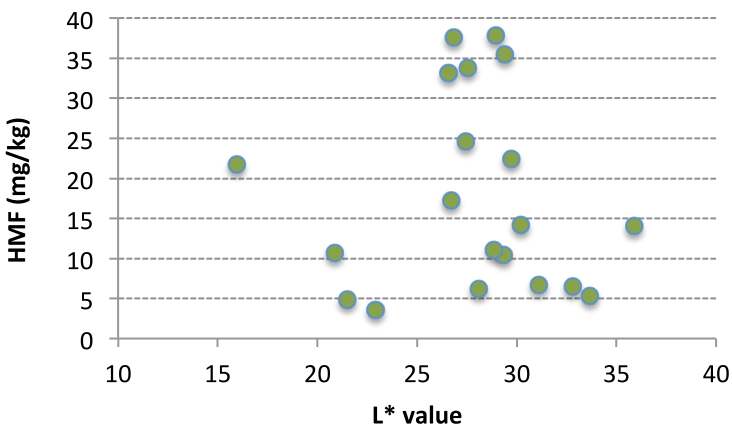

Figure 2 - Levels of hydroxymethylfurfural (HMF) and intensity of browning (L*) of sultanas from vineyards in different areas of Turkey (data extracted from Sevik et al 2014).

Factors that have been demonstrated to increase browning include:

- Slow or uneven drying due to low temperatures and/or high humidity
- Uneven coverage or non-use of drying emulsions (mixtures of oil with potassium carbonate, used to break down the waxy bloom on the grape skin thus accelerating drying)
- Cracking or damage to fruit due to rain
- Irregular irrigation during production, resulting in water stress[7]
- Light crop loads on vines[8]
- Undermature fruit, which initially appear to have a green tinge[9]
- Overmature fruit containing >20° Brix[10] (although no effect of sugars on colour was found by Treeby, 2014[8])
- Extended storage times
- High storage temperatures (eg 30°C)
- Storage in air (low O_2 storage reduces browning[11])
- Storage of fruit containing >13.5% moisture (lack of proper sun-finishing)[12]

The traditional method of drying grapes involved harvesting the fruit and drying on racks. The harvested fruit was usually either dipped in drying emulsion and/or sprayed while on the rack. Fast fruit drying rates are critical to produce light, evenly coloured berries[9].

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[7] Walker RR, Clingeleffer PR. 1993. Quality factors for Australian dried grapes and table grapes. Proceedings of the International Viticulture Conference, Office Internationale de le vigne du vin. Paris, 1993.
[8] Treeby M. 2014. Producing high value dried grapes. HAL project DG13004. Dried Fruits Australia.
[9] Uhlig B. 1998. Effects of solar radiation on grape (*Vitis* vinifera L.) composition and dried grape colour. J. Hort. Sci. Biotech. 73:111-123.
[10] Uhlig B, Clingeleffer P. 1998. The influence of grape (*Vitis vinifera* L.) berry maturity on dried fruit colour. J. Hort. Sci. Biotech. 73: 329-339.
[11] Tarr CR, Clingeleffer PR. 2005. Use of an oxygen absorber for disinfestation of consumer packages of dried vine fruit and its effect on fruit colour. J. Stored Prod. Res. 41: 77-89.
[12] Frank D, Gould I, Millikan M. 2004. Browning reactions during storage of low-moisture Australian sultanas: evidence for arginine mediated Maillard reactions. Aust. J. Grape Wine Res. 10: 151-163.

For emulsion treated grapes, drying occurs in three stages. The first involves rapid evaporation of water from the berry; the second stage is slower, being limited by the speed at which water can move through the fruit; the third stage can require heating to 'finish off' the fruit to the desired moisture content of around 13%, which is necessary for storage[13].

In recent years many growers have converted to swing-arm trellis systems, where grapes are dried while hanging on the cut vines. This allows mechanisation of harvesting and pruning, so has been essential for the continued economic viability of the industry[14]. Drying emulsion is applied using a spray-rig which largely wraps around the vines. Although sprayed with fan forcing using the best method available, it is difficult to fully penetrate the bunches with emulsion applied this way. This effect, combined with shading, means that berries in the centre of each bunch dry more slowly than those on the outside. The result is a more mixed colour in the end product when fruit are trellis dried instead of rack dried.

It seems likely that the increase in mechanisation has inadvertently increased the difficulty in grading fruit, which is now less homogenous within a batch than previously.

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[13] Clingeleffer PR. 197??. Chapter 7 Sultana Raisin production. In "Raisin production, processing and marketing".
[14] Clingeleffer PR, May P. 1981. The swing-arm trellis for sultana grapevine management. Sth African J. Enology Viticulture. 2:37-44.

Measuring colour

What is colour?

Colour is an important quality attribute for all horticultural products. It affects consumer choice and is often used indirectly as an indicator of other quality attributes – such as ripeness, flavour and nutritional value.

In the case of dried vine fruit, colour indicates little about eating quality. Despite this, lightness in colour affects consumer perception and preferences, and adds value to the end product.

Colour is not inherent in objects. What we see as colour is simply different reflected wavelengths of light. It is also a factor of how the human eye perceives those wavelengths then interprets them within the brain. Light sensitive cone cells within the retina are sensitive to long (560-580nm), medium (530-540nm) or short (420-440nm) wavelengths. These correspond approximately to red, green and blue colours, although there are overlaps between the sensitivities of each, particularly between red and green (Figure 3).

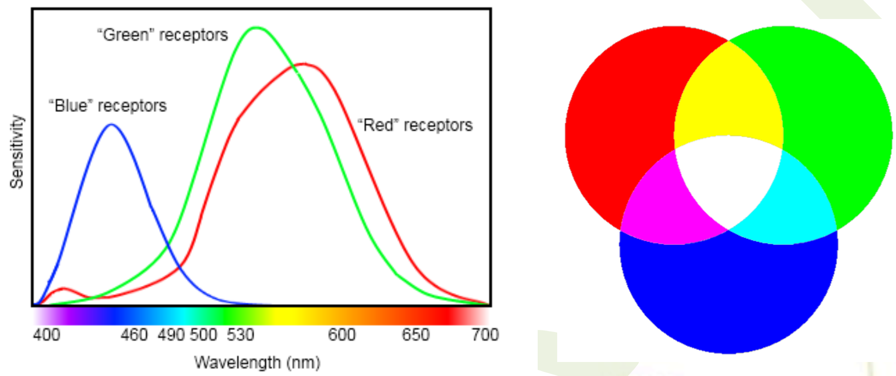

Figure 3 - The wavelength sensitivities of the three types of human eye cone cells, corresponding to blue, green and red colour perception (left) and how these wavelengths combine to create our perception of different colours (right).

The visible light spectrum represents only a tiny part of the electromagnetic spectrum. At shorter wavelengths light enters the ultraviolet range, while longer wavelengths are infrared.

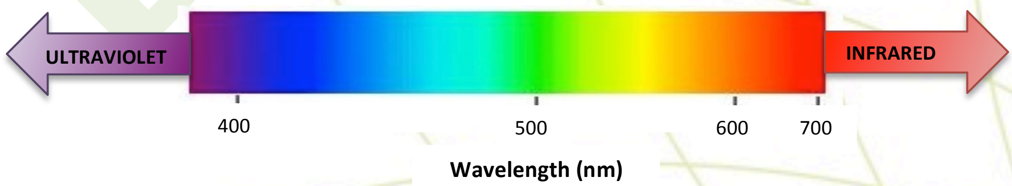

Figure 4 - The visible light spectrum

Colour into numbers

Measuring colour with an instrument means that the colours we perceive have to be converted to numerical values. There are a number of systems for describing colour:

RGB	Red, green and blue. An 'additive' system, where adding more colours = white. Used in video monitors, TVs etc. Red and green LEDs (light emitting diodes) were developed in the 1960's, but it was not until the invention of the blue LED that LED displays could be developed for monitors.
CMYK	Cyan, magenta, yellow and key (black). A 'subtractive' system, where adding more colours = black. Used for printing. CMYK alone cannot repeat all the colours that can be perceived by the eye, so printers use additional 'spot' colours.
CIE XYZ	The CIE XYZ colour space approximates the responses of the red (X), green (Y) and blue (Z) cone cells in the eye. These *tristimulus* values are believed to encompass all the colours that an average person can see, taking into account the sensitivity and overlaps between the different cells and the brightness, or luminosity of the colour. The XYZ space is 'device independent', and is widely used by measuring instruments. However, because it is a three dimensional representation of colour, it is not so useful for human interpretation.
CIE Yxy	The Yxy scale is derived using values from the CIE XYZ calculation. These are used to calculate chromaticity coordinates on a two dimensional representation (Figure 5). The Y value is included as a measure of luminosity.
Hunter Lab	The Hunter Lab scale was developed specifically for photoelectric measurements. It defines colour in terms of L-value, corresponding to lightness or brightness, +a to –a; red to green, and +b to –b; yellow to blue. The L value is a number out of 100, where 100 is white and 0 is black. Values of a and b are not set, but depend on the conversion method and are relative to each other.
CIE L*a*b*	This system superceded the Hunter Lab scale. It was devised to improve the relationship between visually perceived differences and measured values. It is also derived from the CIE XYZ scale, but is easier to visualise. Moreover, a* and b* can be used to calculate hue angle and chromaticity. As these integrate colour values, H° and chroma can be particularly useful tools for comparing subtle differences between samples (Figure 5).

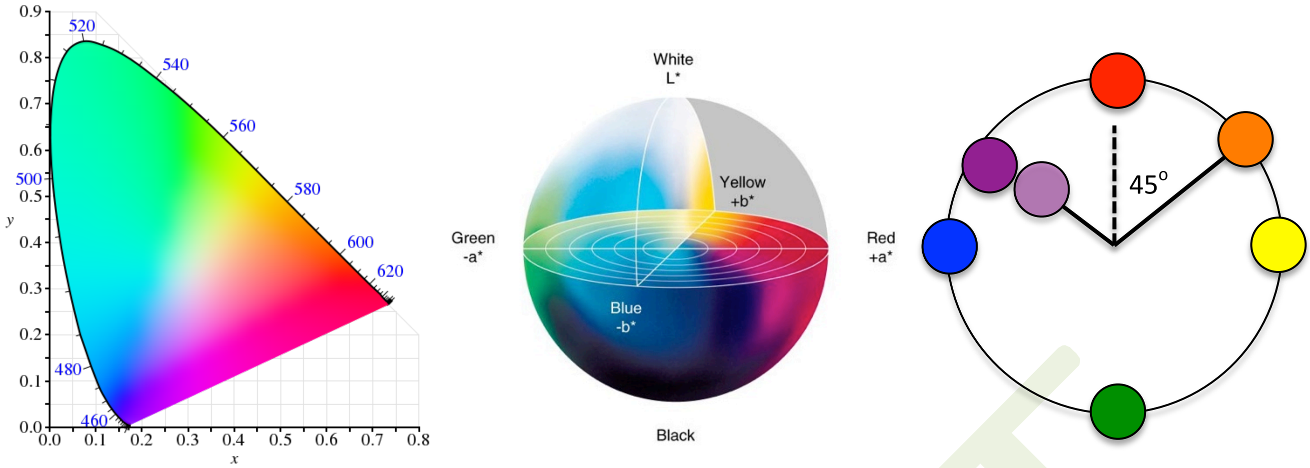

Figure 5 - The CIE chromaticity diagram (left) and L*a*b* three dimensional colour space (centre). The a* and b* values can be used to calculate hue angle and chromaticity (right). Example shows the hue angle for orange, where H°= 45, and two different values of chroma for the same shade of purple.

Adobe Lab — Adobe software such as Photoshop also calculates Lab and hue angle values for each colour. However, numerical values differ from those recorded using the CIE system, such as are reported by a colorimeter. In the Adobe system, a values range from +127 (pink) to -128 (cyan), while b ranges from +127 (gold) to -128 (blue). This results in quite different hue angles to the CIE system (Figure 6).

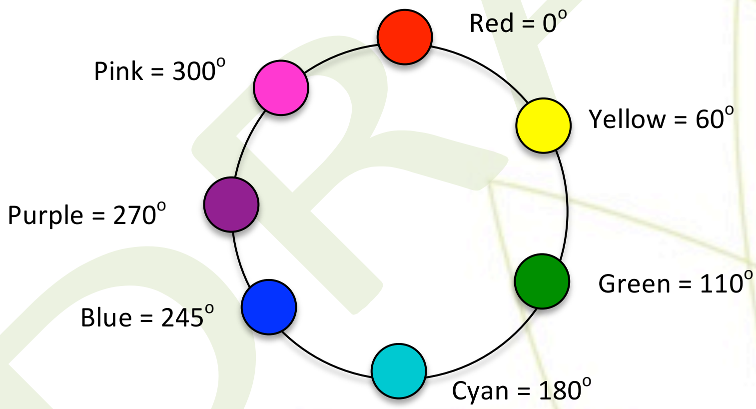

Figure 6 - Adobe colour wheel used to generate hue angle values

Colorimetry

The most common device used for measuring colour of foods, including fruit, is a ***colorimeter***. These instruments record the intensity of wavelengths corresponding to our three types of colour receptors – red, green and blue. Most colorimeters therefore have filters that function like each of these three types of cone cells[15]. They are generally easy to use and provide data that is simple to interpret. Colorimeters have only three main components;

1. A standard source of light
2. A combination of filters
3. A photoelectric detector that converts reflected light into optical output.

The standard light source is chosen according to the way the object would normally be viewed;

Illuminant A – light from an incandescent globe
Illuminant B – direct sunlight
Illuminant C – daylight from the total sky
Illuminant D – improved daylight, identified by their colour temperature eg D_{65}
Illuminant E – fluorescent lamp

The most common device used to measure colour of fruit and vegetables is the Konica Minolta chroma meter. These devices are considered standard equipment in most laboratories involved in evaluation of fruit and vegetable quality. For example, most scientific papers reporting on colour of fruit or vegetables will do this in terms of the output from a Minolta chromameter. They therefore allow ready comparison of data over time, in different locations and for a wide range of products. Other devices include the 'Dr Lange Micro Colour' and the HunterLab MiniScan EZ. Both of these devices can record colour from a maximum 25mm diameter area.

Figure 7 - Konica Minolta CR-400 chroma meter and the HunterLab MiniScan EZ.

Colorimeters measure colour within the space of an 8mm to 50mm aperture. The results are output as L*a*b*, Yxy, H° or a number of other colour scales. The main disadvantage of the colorimeter is the relatively small area that can be measured at once. While multiple measurements can provide a better average over a

[15] Pathare PB, Opara UL, Al-Said F A-J. 2013. Colour measurement and analysis in fresh and processed foods: A review. Food Bioprocess. Technol. 6:36-60.

whole product, they are generally less suitable for products that have a high degree of variation in colour or texture across their surfaces.

Spectrophotometry

Spectrophotometers measure the entire spectral distribution of light reflected from the sample. A spectrophotometer may therefore record not just visible light, but also infrared and ultraviolet. A typical output shows absorbance - and, by deduction, reflectance - at wavelengths ranging from 300-900nm. This can be used to calculate the CIE XYZ tristimulus values, depending on the light source that has been used. These values can therefore indicate the external colour of the product.

As spectrophotometers measure a large range of wavelengths, they can indicate much more about the sample than external colour. Compounds such as chlorophyll, sugars and water all absorb energy at particular wavelengths. This means that devices that measure near infrared reflectance (NIR) can also (non-destructively) estimate;

- Total soluble solids (brix)
- Dry matter
- Internal colour
- Internal breakdown
- Titratable acidity.

In the past interpretation of spectra was complex, spectrophotometers were large and delicate and a dedicated computer was needed to analyse results. This has made them more suited to the laboratory than commercial applications. However, spectrophotometers are now available which are portable, hand held and relatively inexpensive (Figure 8).

Figure 8 - Mini spectrophotometers supplied by Ocean Optics

There are also portable NIR meters designed for use in field applications. One such device is the Felix F-750 quality meter (Figure 9). This device measures wavelengths from 310-1100nm, thereby including wavelengths in the ultraviolet, visual and near infrared regions. It is designed for field applications and can be calibrated for use with different crops and different purposes. It has so far been used commercially with products including summerfruit, mangoes and apples.

Figure 9 - Felix F-750 produce quality meter

As with colorimeters, spectrophotometers measure the average colour over a relatively small area. For most systems, the sampling area is only a few mm across – although various turntable systems are available to take an average over a larger area, and multiple readings may be taken.

Photography and CVS

Both colorimeters and spectrophotometers have the significant disadvantage that only a small area is measured. Small sample size does not matter for homogenous samples, but it makes it difficult to gain a representative reading for products with uneven surfaces or variable colouring. These instruments are therefore unsuitable for assessing colour distribution and uniformity of whole foods – such as non-homogenous sultanas[16].

Digital cameras can effectively record the colour of any size of image, including those with variable colour and texture . Major improvements in camera technology mean that even the camera inside a digital phone or tablet can take a high resolution record of colour.

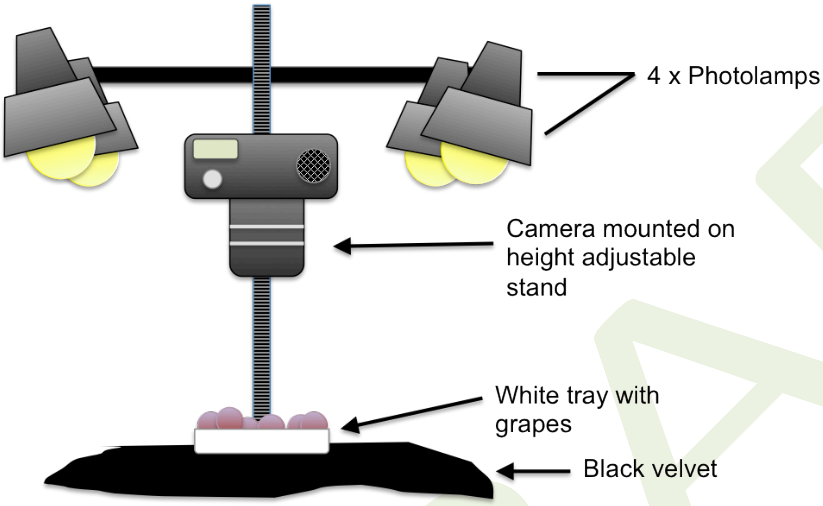

Figure 10 - Camera and lighting for photography of fresh grape samples

The image can then be processed using either external or internal software. A number of phone 'apps' include this function, where colour can be output in one of the colour spaces already noted (RGB, CMYK, L*a*b*). Proprietary software, such as Adobe Photoshop, can also analyse and report on the colour of an image.

Computer vision systems (CVS) are widely used to analyse colour and defects during processing and packing. Even unevenly coloured or textured objects can be sorted quickly and accurately. Cameras can analyse each pixel of the image to determine its colour. This has resulted in CVS measuring qualities as diverse as russet on apples, closed shells on pistachio nuts, amount of chocolate chip in cookies and marbling in sliced beef[17].

CVS is already used to discriminate between light and dark coloured sultanas. However existing systems grade only on lightness and do not include measurement of colour.

A number of issues must be considered when considering a static, rather than in-line, system employing a digital camera,;

16 Hunter RS, Harold RW. 1987. The measurement of appearance. John Wiley & Sons, New York, 411pp.
17 Brosnan T, Sun D-W. 2002. Inspection and grading of agricultural and food products by computer vision systems – a review. Computers Electronics in Ag. 36: 193-213.

- Automatic digital cameras adjust their exposure to achieve similar levels of dark and light within the frame. A dark object is therefore likely to be overexposed, and a light object underexposed.
- Light source is critical to colour perception. While most cameras have an automatic or manual white balance setting to compensate for light source, this is unlikely to be sufficient for accurate colour measurement.
    - D_{65} or D standard lights should be used to simulate daylight
    - Lights should be mounted at an angle of 45°C to the camera
    - Light intensity over the sample should be uniform
- Digital cameras record images in the RGB colour scale. This can be converted to L*a*b*, which more closely approximates human perception. Measurements are also less affected by curved or uneven surfaces than the RGB scale[18]. However, RGB is device-dependant in that values depend on illumination, camera sensitivity etc. Conversion to device-independent L*a*b* units must therefore be done with care[19].

[18] Mendoza F, Dejmek P, Aguilera JM. 2006. Calibrated color measurements of agricultural foods using image analysis. Postharv. Biol. Technol. 41: 285-295.
[19] Leon K, Mery D, Pedreschi F, Leon J. 2006. Color measurement in L*a*b* units from RGB digital images.

Measuring colour of mixed objects

What the dried vine fruit industry needs

Growers and processors need a way to objectively assess sultana grade on receival. The method needs to be fast, simple to operate and consistent, so that all parties trust the results. A rapid assessment tool would allow each incoming bin to be evaluated and allocated a grade, as well as weighed and tagged with stock details, in a single, efficient operation.

A quick and easy method of assessing dried fruit colour could also help processors determine which batches of fruit are storing well, and which are darkening more quickly. This would help prioritise stock for processing, and ensure consistent quality over a longer period of time.

The previous section discussed some of the different ways of measuring colour and the equipment that could be used to do this. However, sultana grade is more than simply an average colour for a batch. Up to three different aspects of dried vine fruit samples need to be objectively measured and compared to critical limits;

- The percentage of dark / black fruit in the batch
- The percentage of fruit with green tinge
- The background colour of the remaining fruit

Existing CVS sorters can only determine dark from light, and in any case are not suitable for rapid assessments of incoming stock.

The following section details some of the systems that have been investigated by other industries that need to assess non-homogenous products.

Establishing a method

León et al. (2006)[19] investigated different methods of converting RGB into L*a*b* color values. This involved calibrating colour tiles measured with a HunterLab colorimeter against measurements taken with a digital camera.

> ***Equipment:*** Canon Powershot camera, 4 Philips Natural Daylight fluorescent lights (18W, 6500K), wooden box with internal walls painted black, Matlab software.
>
> ***Method:*** Photographs taken with a camera inside a blacked out box (Figure 11) were converted from RGB to L*a*b* using five different methods, two of which provided a very close correlation with readings from the colorimeter.

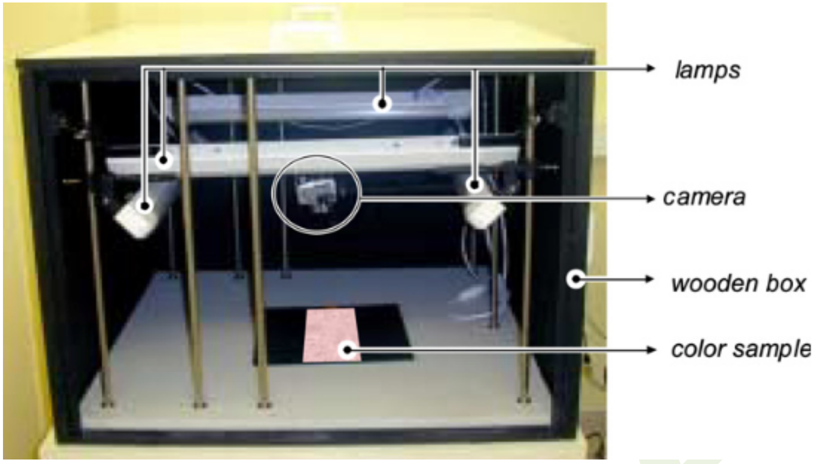

Figure 11 - Setup used to record colour with a digital camera (Leon et al, 2006)

Yam and Papadakis (2004)[20] also aimed to develop a simple method of measuring colour with a digital camera. They tested ways of converting an image from a camera into L*a*b* values relevant to food quality.

> ***Equipment:*** OlympusC-2000Z camera, two D_{65} lamps (Bulb Direct) mounted at a 45° angle to the food plane, image analysis with Photoshop software..
>
> ***Method:*** Photographs were taken of microwaved pizza base with and without different types of browning elements. The images were anlalysed in various ways, including use of a histogram to determine colour distribution ie number of pixels corresponding to values of L*, a* or b*.

There are clear similarities between these two published methods as well as others in the scientific literature. It is clear that digital cameras can be used to measure colour so long as lighting is controlled, calibration colours are included and the image is analysed using some type of software.

[20] Yam KL, Papadakis SE. 2004. A simple digital imaging method for measuring and analysing color of food surfaces. J. Food Eng. 61: 137-142.

Digital cameras

Sun (2000)[21] was one of the first to try to use photographic methods to analyse the percentage area and distribution of different colours in a food. The team used a CVS to inspect pizzas with different types of toppings.

> ***Equipment:*** Sony 3CCD camera, IC-RGB frame grabber (Imaging Technology, USA), image analysis software that grouped pixels together based on homogeneity criteria.
>
> ***Method:*** Pizzas were photographed under standard lighting. Each image was then divided into quarters and four equal area radial sections. The percentage of toppings in each section was compared. Differentiating pepperoni from tomato sauce and red pepper was possible using regional segmentation, which groups pixels together. This made it possible to calculate the percentage of each topping in each area of the pizza (Figure 12).

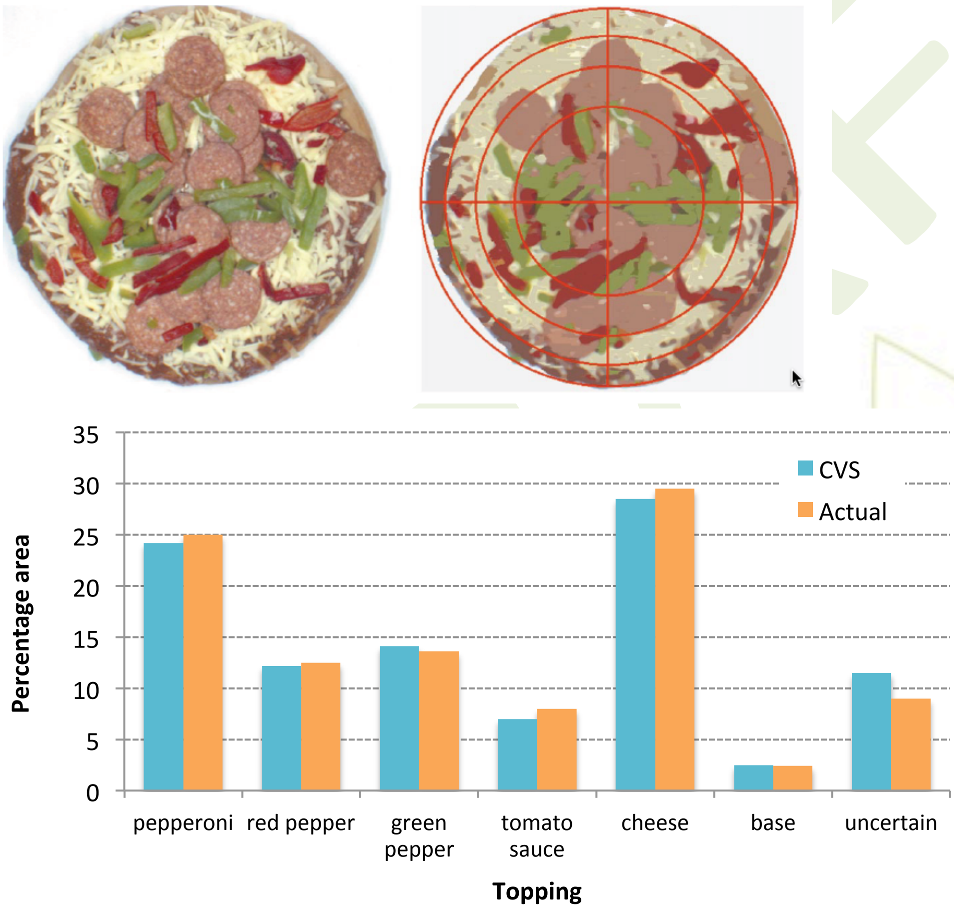

Figure 12 - Original image of a pizza (top left) and the segmented version converting each ingredient to a colour value (top right). Graph shows the computed and actual percentages of each topping (Sun, 2000).

[21] Sun D-W. 2000. Inspecting pizza topping percentage and distribution by a computer vision method. J. Food Eng. 44: 245-249.

Davidson et al. (2001)[22] used digital images to estimate physical features of chocolate chip cookies. Features analysed included size, shape, dough colour and percentage of top area covered with choc chips.

Equipment: JVC camera linked to a lab computer, two fluoro lights (15W), software The Image Vision library (Silicon Graphics) plus a feature extractor programmed in C++ (UNIX).

Method: The feature extractor identified cookie perimeter, average diameter and portion of total area that was chocolate chips (Figure 13). RGB colour values were transformed to CIE XYZ then to L*a*b*. The L* value was used to identify chocolate chips.

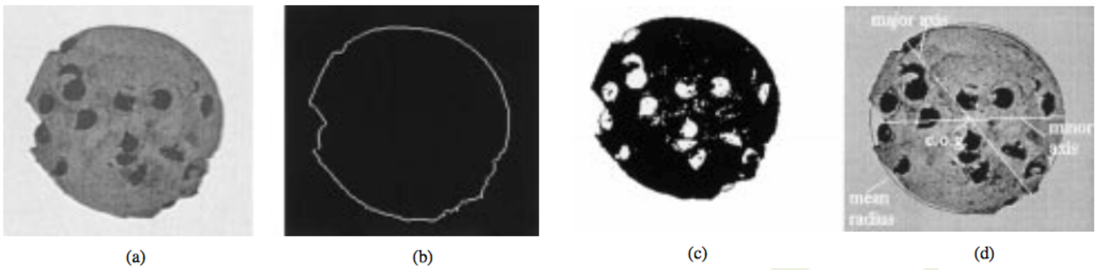

Figure 13 - Analysis of a chocolate chip cookie; a. original image b. perimeter definition c. choc chip definition d. dimensions (Davidson et al 2001)

The aim of the work of Pedreschi et al. (2006)[23] was to develop and implement an inexpensive CVS for measuring color of a highly heterogeneous food material – both in color and shape. They therefore chose to analyse potato crisps, segregating chips with discoloured or burned areas.

Equipment: Canon Powershot camera, 4 Philips Natural Daylight fluorescent lights (18W, 6500K) arranged at an angle of 45° to the sample plane, white balance using grayscale from Kodak, wooden box with internal walls painted black, Matlab software.

Method: Photographs taken with the camera inside a blacked out box were converted from RGB to L*a*b* using the method described by Leon et al[19]. Dark sections of individual chips could be selected and differentiated on the basis of L* value

[22] Davidson VJ, Ryks J,Chu T. 2001. Fuzzy models to predict consumer ratings for biscuits based on digital image features. IEEE Trans of Fuzzy Systems 9: 62-67

[23] Pedreschi F, Leon J, Mery D, Moyano P. 2006. Development of a computer vision system to measure the color of potato chips. Food Res. Int. 39: 1092-1098.

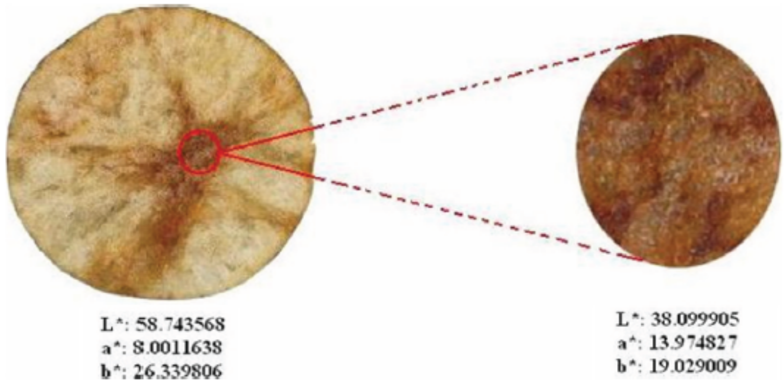

Figure 14 - Analysis of dark area on cooked chip, showing difference in L* value (Pedreschi et al. 2006)

Mendoza and Aguilera (2004)[24] also used CVS to analyse the percentage area of brown spots compared to background colour. In this case, they examined brown spots on the skin of bananas.

> ***Equipment:*** Nikon Coolpix camera, 4 Philips Natural Daylight fluorescent lights (18W, 6500K) arranged at an angle of 45° to the sample plane, light diffusers added to ensure even distribution of light, white balance using grayscale from Kodak, wooden box with internal walls painted black, Matlab 6.5 software.
>
> ***Method:*** Photographs taken with the camera inside a blacked out box were pre-processed to smooth the image using a Gaussian filter. The image was segmented from the background using a threshold of 50 combined with an edge detection technique. Colour data was converted to L*a*b* and segmented pixesl were used to record the colour of the banana. These values were compared to readings from a HunterLab colorimeter. The a* value was determined to be the best indicator of a dark spot. The images were binarised using a threshold value of a*≥130. This allowed calculation of the percentage area of brown spots and number of brown spots/cm^2. Only spots with an area >5 pixels (0.05cm^2) were considered.

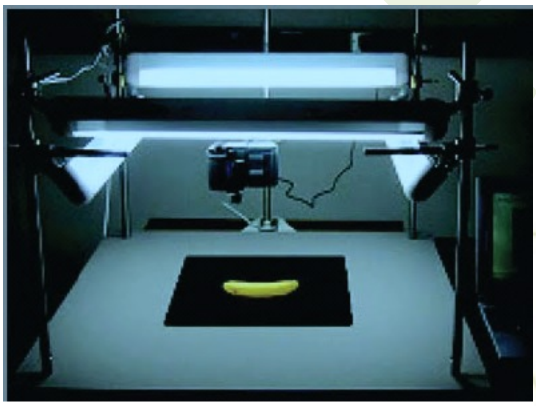

Figure 15 - Setup of camera and lights to record banana colour and spots (Mendoza and Aguilera, 2004).

[24] Mendoza F, Aguilera JM. 2004. Application of image analysis for classification of ripening bananas

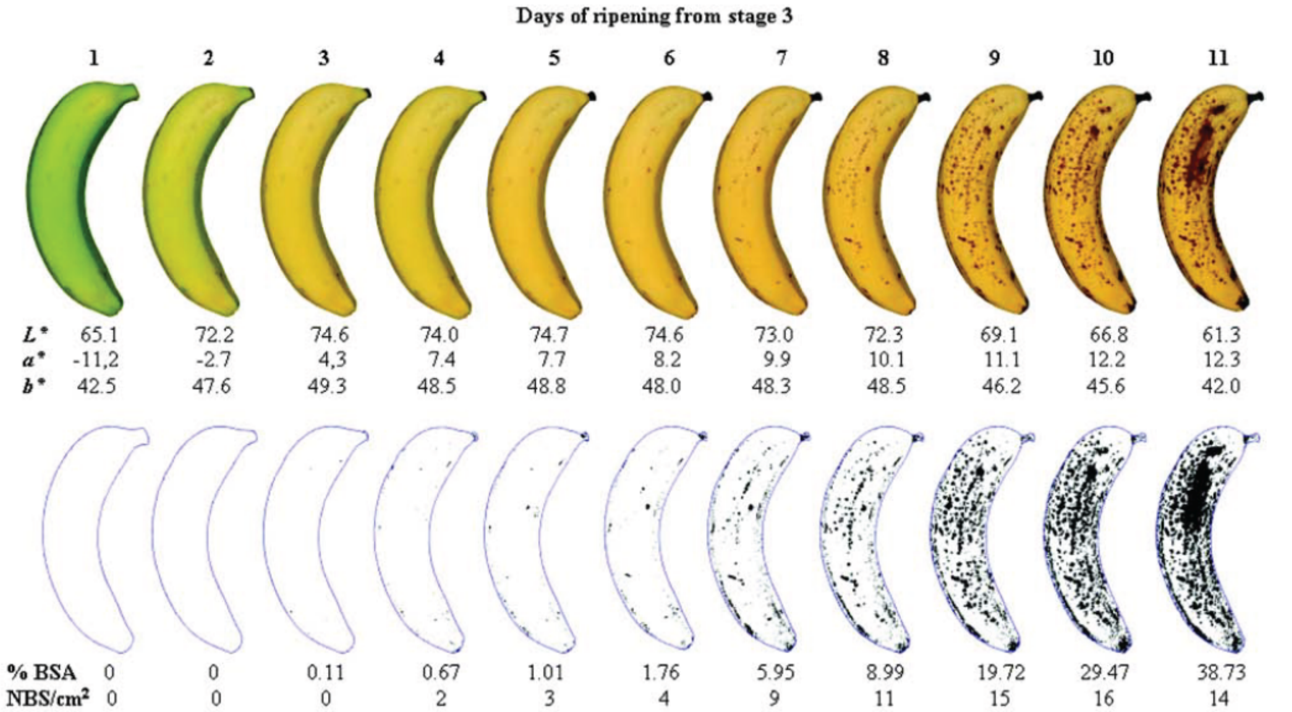

Figure 16 - Original (top) and analysed images of a banana during ripening (Mendoza and Aguilera, 2004).

Flatbed scanners

Flatbed scanners are also effectively cameras. In this case, they have the advantage that lighting is standardised, with external sunlight or fluorescent light almost fully excluded.

Shahin and Symons assessed lentil variety by pouring the sample into a clear sample tray and taking an image using a flatbed scanner[25]. A software program – LentilScan – was developed to separate individual lentils and segregate five different varieties according to size and colour. The whole operation took 30 seconds to complete, with less than 1 second for the actual analysis and the remainder used in operator input and scan time.

Whan et al (2014)[26] used a similar approach. The primary aim of this work was to measure grain size, as well as colour, for different grain species. Rather than a camera, they used a normal, consumer grade scanner to record the image for analysis.

> ***Equipment:*** Canon and Epson consumer grade scanners (<$250), image capture through VueScan at 300dpi with no colour adjustment.
>
> ***Method:*** Grains were scattered separately onto a glass bottomed tray and placed in the scanner. Matt black cardboard was placed on top to minimize reflection and shadows. A Munsell

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[25] Shahin MA, Symons SJ. 2013. Lentil type identification using machine vision. Can. Biosys. Eng. 45: 3.5-3.11

[26] Whan AP et al. 2014. GrainScan: a low cost, fast method for grain size and colour measurements. Plant Methods 10:23.

ColorChecker mini card was included with each scan and this was use to generate conversion parameters for the colour infromation. Images were analysed using GrainScan software. This separates the grains from the background using a thresh-holding method, applies Gaussian smoothing to the image to remove noise, and adjusts colour using the Munsell scale. Colour was correlated with measurements made using a Minolta chromameter.

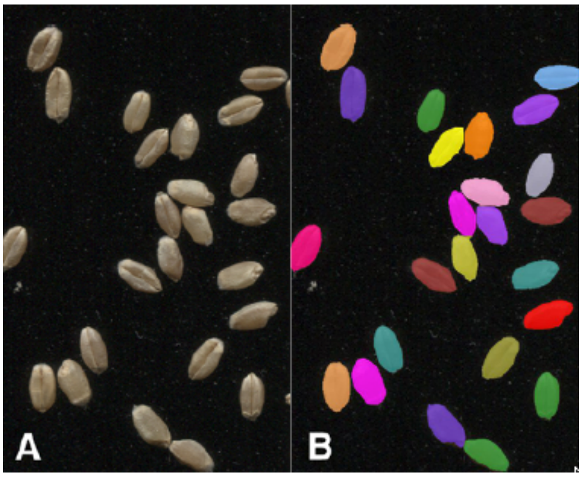

Figure 17 - Image of wheat grains taken with a flatbed scanner, then with grains selected individually by GrainScan software (Whan et al. 2014).

Alex Whan has been contacted about this work to discuss whether it could be applied to dried grapes. His comments were;

> *"I'm sure it could be applied. Colour is what I was particularly interested in when we developed GrainScan. Of course I can't be sure how it would perform since it was specifically designed for wheat grains, and some of the image segmentation uses colour information, but I would expect it to be able to work. It would certainly be the lowest cost option I know of. We use consumer grade ($150 - $200) scanners."*

Another example was the use of a flatbed scanner to measure the amount of contaminants ('dockage') in harvested canola[27]. Canola containing different amounts of dockage was imaged using a flatbed scanner, with the calculated L* as well as RGB values used in the analysis. The amount of dockage was calculated by discriminant analysis using the Proc GLM and Proc Discrim procedures in SAS statistical software.

In this case the model based on colour alone was not sufficiently accurate to provide the desired result. However, this work did confirm that scanners can provide a fast, two dimensional image that can be further analysed.

[27] Dilawari G, Jones CL. 2013. Quantification of dockage in canola using a flatbed scanner. Trans. ASABE. 56: 1969-1975.

Smartphones

A number of recent papers have reported using smartphones for various types of colorimetric analyses.

Smartphone cameras have huge potential for use in analysis of colour. Much of the research in this area so far has focussed on medical uses, where colorimetric diagnostic tests can confirm presence or absence of a compound. For example, there are reports of using smartphones to analyse the colour of infant's stools to determine if they are suffering from biliary atresia[28], to detect glucose in urine as an indicator of diabetes[29] and to measure alcohol content in saliva[30].

Even though these applications are mainly measuring the colour of a standard test strip, calibration remains an issue. Smartphones are generally optimised for use in bright, outdoors conditions. Differences in light intensity and wavelength are likely to affect results (Figure 18). Researchers have tried various ways of solving this issue, including mounting the device in a housing unit that included battery driven LEDs and additional lenses. If all that is being read is a test strip, then this housing can be miniaturised and attached directly to the phone (Figure 19).

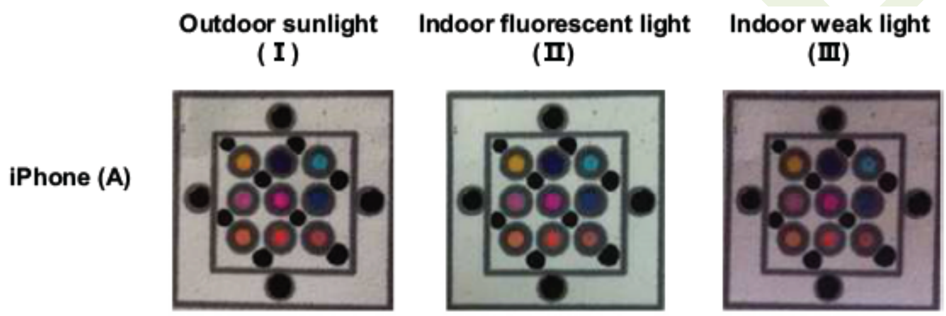

Figure 18 - Images of colour based arrays taken under different light conditions using an iphone (Jia et al, 2015).

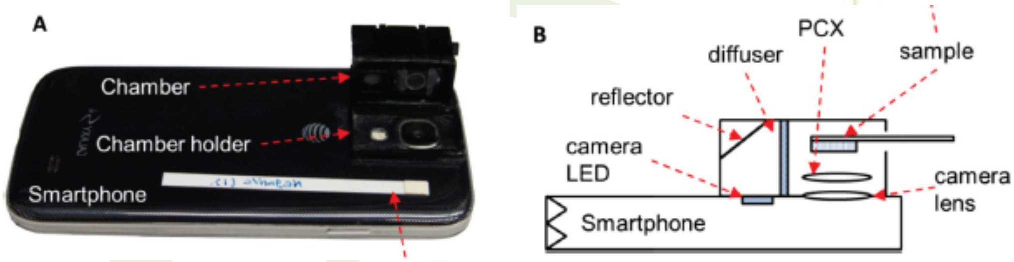

Figure 19 – Photo (A) and schematic diagram (B) of a colorimetric imager designed for a Samsung Galaxy S4 (Jung et al, 2015).

[28] Franciscovich A. et al. 2015. PoopMD, a mobile health application, accurately identifies infant alcoholic stools. PlosOne DOI:10.1371

[29] Jia M-Y et al. 2015. The calibration of cellphone camera-based colorimetric sensor array and its application in the determination of glucose in urine. Biosensors Bioelectronics 74: 1029-1037.

[30] Jung Y et al. 2015. Smartphone-based colorimetric analysis for detection of saliva alcohol concentration. App. Optics 54: 9183-9189.

An alternative is to use black and white, or other standardised colour tiles, to calibrate the camera. However, a simple calibration with white balance does not necessarily compensate for differences in shooting distance, imaging angle or phone type. Jia *et al*. proposed a grid, which includes a white background as well as an array of black spots (Figure 18). These calibration points may be managed externally, or internally through the smartphone software and can correct for angle as well as lighting and colour caste.

An alternative method was proposed by a group from the University of Cambridge. The team developed an algorithm for use with smartphones to analyse colourimetric samples (Figure 20). Calibration images are recorded first. The user then selects the type of test to be performed and takes an image of the sample itself[31]. The app then reports the corresponding data, such as pH, protein content etc.

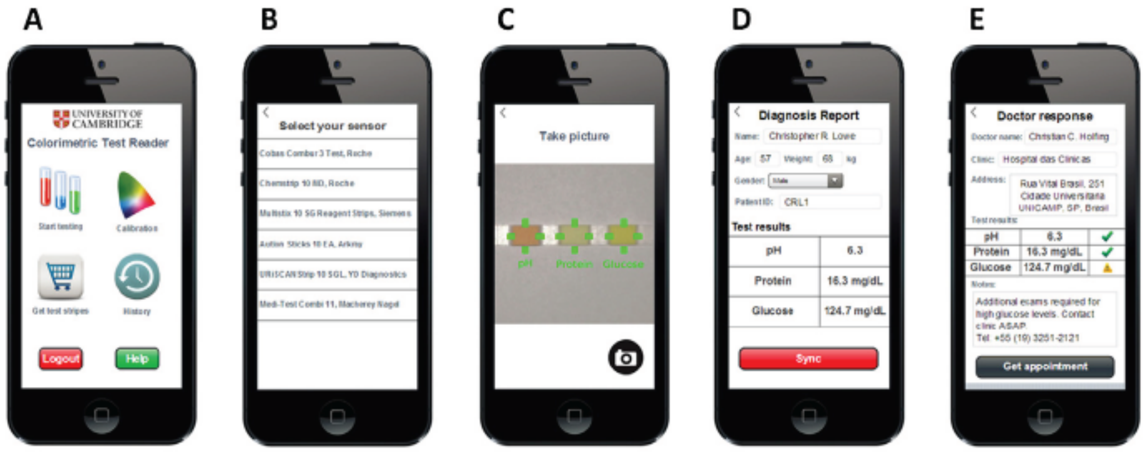

Figure 20 - Screenshots of the IOS app developed by Cambridge university. A-Main menu, B-Sensor types, C-Image of the test strip, D-Diagnostic test results, E-User instructions (Yetisen et al. 2014).

[31] Yetisen AK et al. 2014. A smartphone algorithm with inter-phone repeatability for the analysis of colorimetric tests. Sensors and Actuators B: Chemical 196: 156-160.

Colours of dried sultanas

Colour delimiters

In order to sort dried sultanas by colour, the first step is to set delimiters for what is meant by light or brown, as well as amber or green tinge.

Adobe Photoshop provides a number of tools that are easily used for colour analysis. While software such as this is likely to be too complex for use in a commercial situation, it can provide useful baseline information, which can potentially be incorporated into a custom-built analysis tool.

An example is shown in Figure 21. The range of colours in a typical batch of dried grapes is shown at top. In the following photograph the colour of each berry has then been averaged, and the L, a, b and hue angle values for each colour recorded using Adobe Photoshop. As shown in the graphs following, L value − corresponding to overall brightness − is highest for berries 2 to 5. In contrast, a value − corresponding to red or pink − is highest for berries 4 to 11. The value of b follows a similar pattern to that shown for L (brightness), whereas hue angle indicates a steady change from approximately 45 to 12 as the berries darken. Hue angle appears to be an effective discriminator of the different colour berries, and was also used to differentiate samples by Treeby (2014)[8].

These results suggest that a combination of values may be needed to differentiate dark and green tinged fruit from those that are light amber or with greenish tinge. For example, a simple browning index value calculated as 'Hue – (L + a)' could be used to segregate light fruit (browning index ≤-20) from dark or green tinged fruit (Figure 22).

The suitability of such delimiters needs to be set by industry to ensure they properly reflect commercial needs.

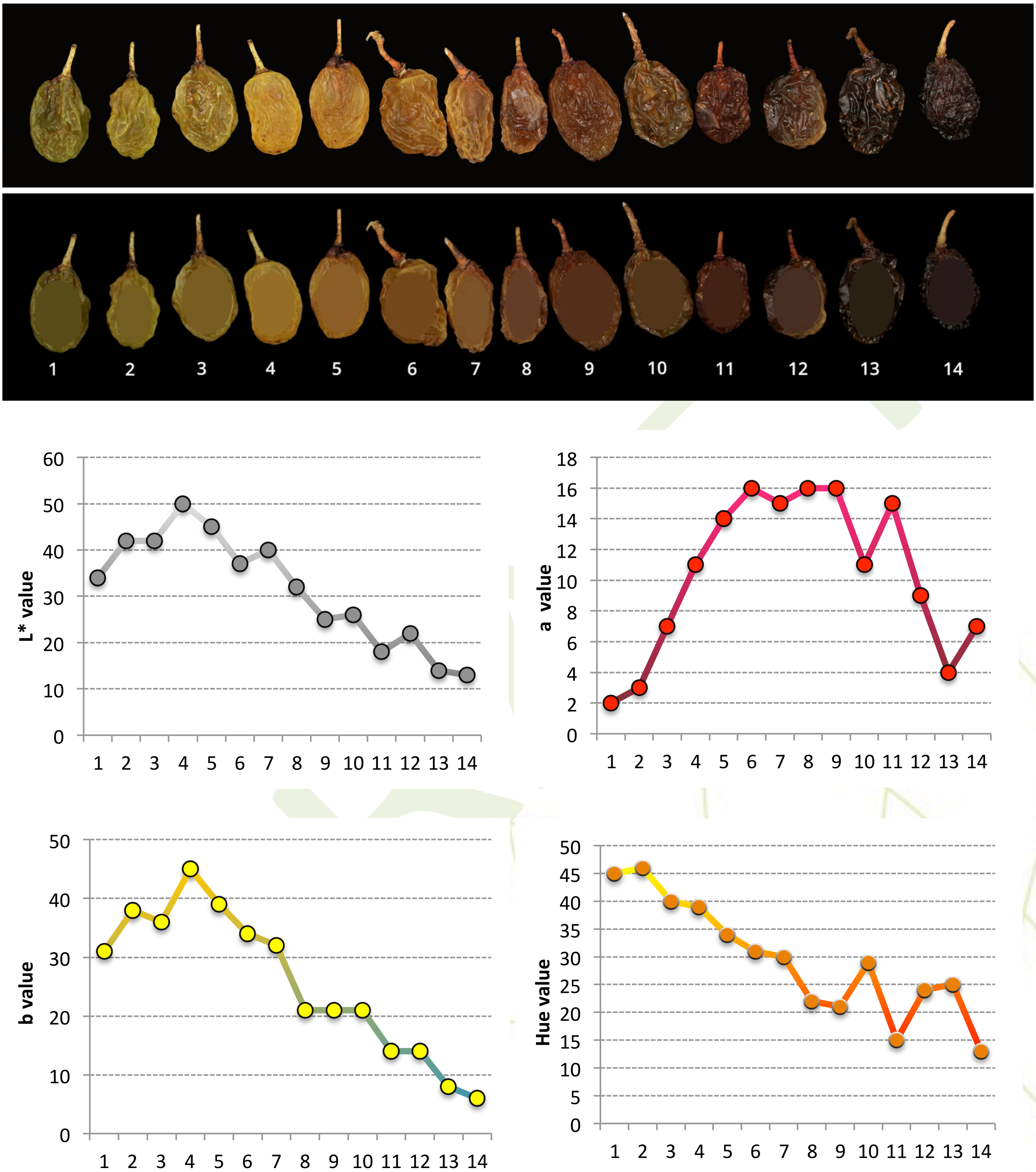

Figure 21 - Colours of dried grapes. Original picture shown at top, and with colour of each berry averaged below. The fruit numbers correspond to the L, a, b and hue angle values shown in the graphs above.

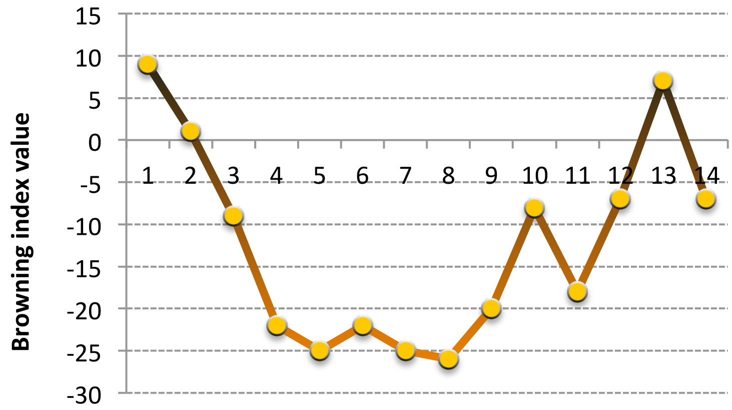

Figure 22 - Example of possible browning index, calculated using Adobe Photoshop colour values. Index number = Hue - (L + a). Light fruit have a browning index value of -20 or less.

Colour analysis software

There are a number of different software systems that can analyse colour. Photoshop is a clear leader in terms of the ability to manipulate photographs. However, Photoshop is designed for graphic image creation and artwork, not for analysis of images, so this is not straightforward. While Photoshop can set a threshold value, or reduce pictures to a certain number of colours (Figure 23), it is not easy to determine the percentage of a particular image that falls within certain, predetermined colour or brightness parameters.

Figure 23 - Original picture of sultanas (left) and reduced to four colours (posterise function) in Photoshop (right)

Software packages such as Image Pro are more specifically designed for image analysis. Software such as this allows the user to outline, count or classify objects. For example, the same image of sultanas as shown in Figure 23 may be analysed to show the number of brown, green or golden coloured fruit.

Figure 24 - ImagePro analysis showing original (left) and divided into brown, green and yellow fruit (right). The software can provide an analysis of the percentage of each object within the image.

There are a number of existing apps designed to measure the area of, for example, diseased and non diseased leaf tissue. The Leaf Doctor app for iphone allows the user to estimate the percentage by area of diseased tissue on a leaf. This is done by selecting colours that represent healthy tissues, then moving a slider until the diseased tissues have been transformed into a blue hue. The pixels are counted to calculate the percentage of disease. This may then be compared to a threshold value.

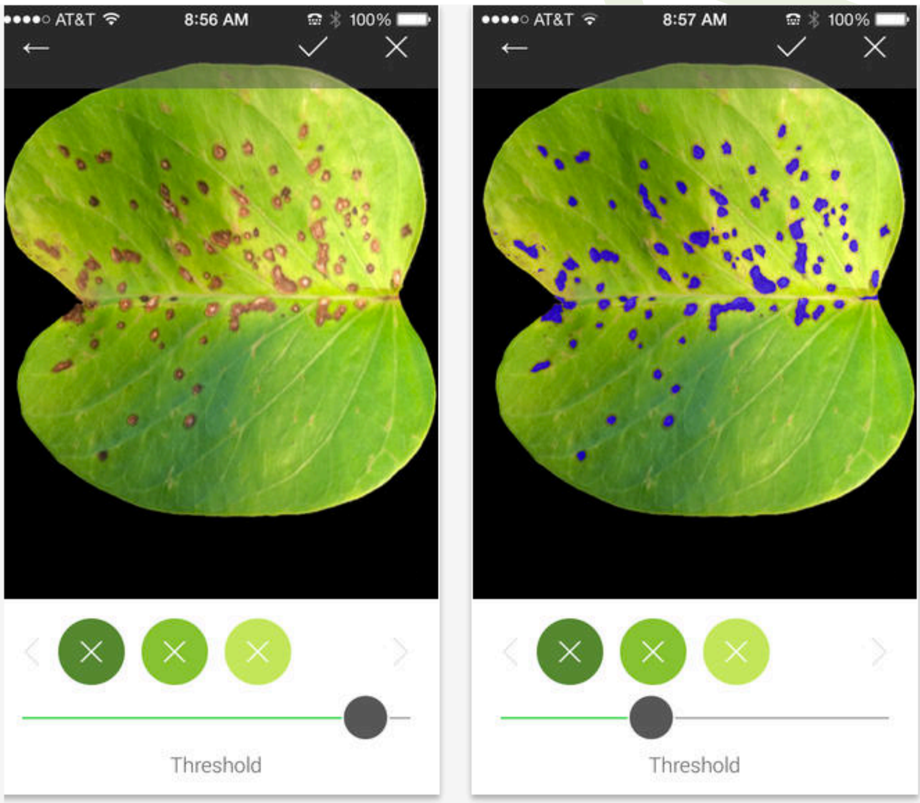

Figure 25 - Image from Leaf Doctor app.

Similarly, the free software program 'Black Spot' (www.ncbs.res.in) can estimate leaf area from images captured on a flatbed scanner. Unfortunately this software simply reduces the image to black and white. Nevertheless, this demonstrates that if appropriate colour delimiters can be developed, then calculation of percentage area is relatively simple.

Figure 26 - Images from 'black Spot' leaf area estimating software (ncbs.res.in)

'Easy Leaf Area' is another free software program that can be used to calculate leaf area. In this case, the software is designed to use with images taken on a mobile phone, but analysed on a computer. It is claimed that this method is more accurate than calculations made using images on a flatbed scanner, as a red calibration tile is included with the image. The software searches for and scans the tile in order to calculate the green leaf area[32]. A mobile version is reported to be under development.

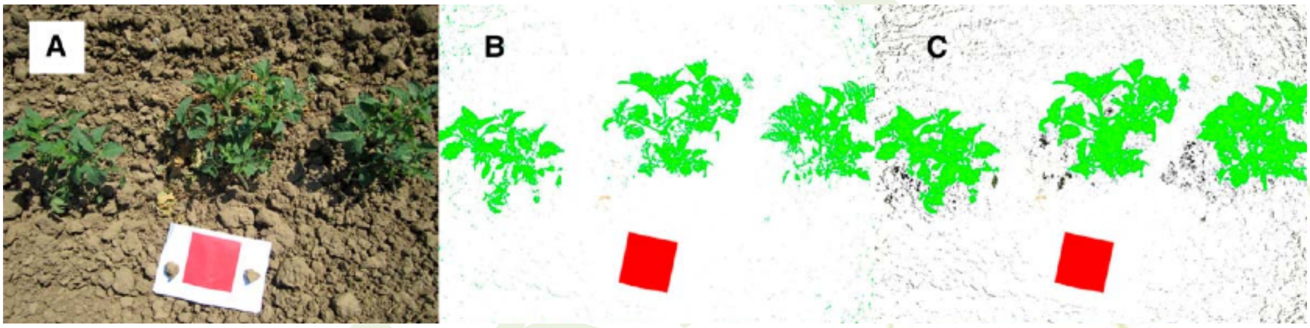

Figure 27 - Images of tomato seedlings analysed by Easy Leaf Area software (Easlon and Bloom)

[32] Easlon HM, Bloom AJ. 2014. Easy Leaf Area: Automated digital image analysis for rapid and accurate measurement of leaf area. Appl. Plant Sci. 2: 1400033.

Summary and Recommendations

Summary of findings

There are a range of different devices that can be used to measure colour of dried fruit. These are summarised in Table 2.

Table 2 - Advantages and disadvantages of different devices for measuring colour

Colour measurement method	Advantages	Disadvantages
Spectrophotometer **eg Felix F-750, mini-spectrometers**	Can provide information about internal properties (sugars, moisture) as well as surface colour	Small sampling area – difficult to get a representative measurement if the sample is non-homogeneous
	Combined with appropriate software, can give extremely accurate readings	Needs to be regularly calibrated
		Data can be difficult to interpret
		Provides average of sampling area only – cannot distinguish between light and dark fruit
		Some devices are fragile – laboratory instruments only
Colorimeter **eg Konica Minolta chromameter**	Standard piece of equipment used around the world – results comparable with other laboratories, countries etc.	Small sampling area – difficult to get a representative measurement if the sample is non-homogeneous
	Fast results in a range of different colour space values	Provides average of sampling area only – cannot distinguish between light and dark fruit
	Data is presented already in L*a*b* colour space	Does not usually provide a pass or fail, simply data
Digital photography / computer vision system	Sampling area is unlimited – large amount of fruit could be analysed simultaneously	Software would need to be designed specifically for purpose, potentially adding significant cost
	Can analyse the number of pixels within certain critical limits for attributes such as darkness (L* value), green tone (a* value) and report as a precise percentage	Lighting is critical – need to standardise exposure, white balance
	Record is permanent, allowing further analysis or checking at a later date	Readings may be affected by shadows, sticks, leaf etc
	Could be largely automated	
	Simple camera such as phone or	

	tablet may provide sufficient image resolution, reducing cost	
	Analysis tool could be developed so as to fit with existing record keeping systems	
	May be possible to use a flatbed scanner to take photographs	

Digital cameras and computer driven CVS appear to have many advantages over traditional methods such as colorimeters and spectrophotometers. There are also other technologies – such as using a simple flatbed scanner − which remain to be tested for use with dried vine fruit.

Lighting is likely to be a critical factor in use of photographic methods for image analysis. It is also not yet clear whether dried fruit would need to be analysed in a single layer, against a standard white or black background, or whether a photograph of the fruit as it arrives, bulk loaded into a bin, will be sufficient to give an accurate result. Analysis of an unstructured batch of fruit would be faster and more convenient to users, but may reduce accuracy compared to a more structured setting.

This review of existing technologies failed to find any software programs that could easily be used to determine the number of dark fruit in a batch, or record the colour of non-dark fruit. However, a number of software programs with similar, or even more complex functionality, were found. It is likely to be possible to adapt an existing program, or even produce an entirely new software program, to interpret and analyse images of dried grapes.

Whichever option proves viable, setting appropriate colour delimiters will be critical to success. These need to be determined in close consultation with industry.

Next steps

There would appear to be little potential for use of a colorimeter or spectrophotometer to measure the colour of dried grapes. These devices are restricted in their capacity to record different colours and lightness grades within a batch, as well as by the area of product that can be sampled.

However, the many different forms of digital photography suggest a range of possible techniques as well as greater accuracy in grading, as long as a practical method can be developed.

- Images of different grades and colours of dried vine fruit should be recorded using a flatbed scanner, digital camera and smartphone. Images may be taken in a single layer, in bulk, or on a variety of different backgrounds.
- Images may be processed using existing software (Photoshop, ImagePro) to analyse the different colours within batches. These values may be compared with readings from a Minolota chromameter, this being the standard tool used for measuring colour.
- Colour delimiters for different grades and acceptability of dried vine fruit need to be determined in consultation with industry representatives. These may utilise one or several different colour space systems. It may be useful to develop a 'browning index' or similar, which combines several different parameters.
- IF it appears likely that photography of a batch of fruit will provide sufficient data for accurate grading and analysis, then a prototype photographic box system, using daylight illuminants set at a 45° angle to the camera, should be developed for use with smartphone or tablet device.
- Pictures and delimiters should be discussed with software designers to determine the likely cost and level of difficulty to develop a 'bespoke' software system for dried grape colour analysis. It should be noted that (ideally) any such system should be designed for easy incorporation into existing supply chain practices.

Attachment 2 – Dried fruit reference group

Contacts

DFA Association

Phil Chidgzey, DFA CEO
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M: 0439 733 321

John Hawtin, DFA Industry Development Officer. Also, a former grower
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Growers

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Email: markrk1@bigpond.com

Peter Jones, Former Chairman, DFA — CARDROSS
Email: jones_pj4@hotmail.com

Stephen Bennett, Deputy chairman, DFA. — MILDURA
Email: stephenbennett1@bigpond.com

Ivan Shaw, DFA board member — MILDURA, near airport
Email: ihjashaw@gmail.com

Processors

David Swain, Supply Manager, Sunbeam Foods
1 Waltham Ave, Irymple
Email: dswain@sunbeamfoods.com.au
Glenn Shaw – Redcliffs – fruit classer

Adam Surgey, Australian Premium Dried Fruits
Wargan Rd, Merbein South
Email: adam@apdf.com.au
(CEO – Mike Maynard)

Mick Leslie, Australian Premium Dried Fruits
Fruit classer / production manager
Email: Michael.Leslie@apdf.com.au

Meeting of Project Reference group

DFA office, Mildura
5:30pm, Monday 15th February

Present:

John Hawtin (IDO DFA)
Mark King (Grower, chairman DFA)
Stephen Bennett (Grower, deputy chair DFA)
Peter Jones (Grower)
Ivan Shaw (Grower)
David Swain (Processor, Sunbeam foods)
Jenny Ekman (AHR)

Apologies:

Phil Cidgzey (CEO DFA)
Anthony Kachenko (HIA)
Adam Surgey (Processor, APDF)

The meeting commenced with Jenny giving a quick rundown on the project outline, with particular reference to tasks 1, 2 and 3.

One of the key purposes of the reference group is to consider the review of available methods of measuring colour and different technologies, and prioritise these for further work within Task 3. This is a Stop:Go point for the project, and needs to be completed by **18th March.**

Jenny then presented some of the work AHR previously conducted for Bayer measuring the colour of Red Globe table grapes.

While there are some good lessons from this work, it was felt that averaging a sample may not be appropriate in this case. Dark fruit need to be recorded and subtracted from the sample, as this is what will happen during processing. Or, at least this needs to be done for otherwise light coloured samples. More than 30% dark samples will not be processed this way as it causes too much damage to the fruit.

It was unclear exactly how the colour vision system sorts fruit, but it is primarily on lightness only, not colour. The maximum dark shade allowed is set by the operator. Unfortunately, rejecting dark fruit inevitably also rejects some light fruit, increasing wastage. It is therefore only economic to colour sort fruit for export markets if it is predominantly light.

Current grading is therefore not just on the basis of Crown grade (which largely refers to the percentage of dark fruit in the sample), but also on ‘light’ or dark’, which refers to the base colour of the fruit.

The method therefore needs to record both percentage dark or brown fruit AND the average ground colour of the remainder.

In a photograph, shadows will also appear dark – there was a discussion about flattening a sample, using for example a glass sheet, to eliminate shadows and get a better reading.

Leaf trash should also be excluded, if possible, as this will make the reading appear lighter.

The group also discussed sample size, and the need for repeatability. The instrument used to measure colour should ideally use a sample approximately the size of an A4 sheet of paper. There are approximately 240 sultanas in a 100g sample, so a 400g sample would contain close to 1,000 fruit and be representative.

If the instrument is portable, perhaps it could bluetooth to the barcode allocated to each bin on receival, and the weight of that bin. This should be considered, as would greatly increase efficiency.

If the method takes a while to set up this will be OK, as it won't need to change much. There was discussion about how colour changes between seasons. The new colour assessment method may therefore not use the existing crown grade system, but rather generate a number / letter. This could be linked to a crown grade if needed / expected by customer. However, the main export market in Germany expects consistent quality every year, so changing what is meant by the crown grade is not appropriate for this market.

The main target for this technology is bin assessment by processors when fruit is delivered. Ideally it should be fast, portable, and able to be conducted on every bin of unprocessed fruit as it arrives. If tools can be provided to growers for self assessment as well, that would be a bonus.

ACTION ITEMS:

Jenny to review available methods, technologies and costs. Report back in time for next meeting. Initial study of grape colour using samples obtained on this trip can feed into Task 3 activities. David to find out more about colour vision sorter and give Jenny supplier details to investigate.

Meeting closed 7:00pm

NEXT MEETING – Wednesday 16th March at 7:30pm at the DFA office (with pizza provided)

Meeting of Project Reference group

DFA office, Mildura
7:30pm, Wednesday 16th March

Present:

John Hawtin (IDO DFA)
Stephen Bennett (Grower, deputy chair DFA)
Peter Jones (Grower)
Adam Surgey (Processor, APDF)
David Swain (Processor, Sunbeam foods)
Peter Clingeleffer (CSIRO)
Jenny Ekman (AHR)

Apologies:

Mark King (Grower, chairman DFA)
Ivan Shaw (Grower)
Anthony Kachenko (HIA)

The meeting commenced with Jenny presenting the results of the review. This was also provided to attendees as a hard copy so they could examine the findings in more detail.

Peter C noted that a number of additional references should be included. These included a recent milestone report by Michael Treeby (where he measured dried grape colour using a Minolta colorimeter), a book chapter by Peter and papers published within CSIRO journals by Michael Grncarevic in the 1970's.

There was considerable discussion around the values recorded for different colours of grapes. It was agreed that more than one value would be needed to segregate dried fruit into different categories. There was considerable interest in the different software available, although it was agreed that none of these were absolutely what was needed for the current project.

As variability / number of dark fruit is a key issue, the group agreed that photographic methods were the most likely to be suitable.

There was debate around whether the method should be one that growers could also use, or focused only on the processors. Some of the group felt that growers taking their own measurements was not necessary, however it raises the possibility that growers could further segment their crop to reduce variability, thereby effectively adding value.

The 'Next Steps' were discussed. None of the group disagreed with these actions.

Mark King previously emailed that there needs to be a clear focus on colour measurement, moisture being less relevant. However, David Swain commented that if a method of moisture content measurement could be assessed within current activities this would be a major benefit to the industry.

ACTION ITEMS:

- Add additional references to review, contact Michael Treeby direct for his input.
- Collate samples of different grades and photograph using different methods (camera, flatbed scanner).
- Develop delimiting values for green, light, dark etc. using at least 100 individual fruit.
- Software developers to be contacted for indicative pricing on analysis software based on delimiters and images provided.
- Potentially develop prototype system based on the type of software that could be suitable

Meeting closed 9:45pm

NEXT MEETING – To be determined (likely July – August)

Objective colour measurement of dried grapes – a Review

Jenny Ekman

ahr applied horticultural research

The issue

- Quality grades for dried vine fruit are strongly related to colour
- Colour is currently assessed subjectively on the basis of
  - Number of dark fruit ; Crown Grade
  - Base colour of remaining fruit ; Light or Brown
  - Presence of green tinged fruit
- Colour strongly affects prices paid to growers
- Need to develop a fast, non-destructive and objective method to measure fruit quality

Grades of sultana

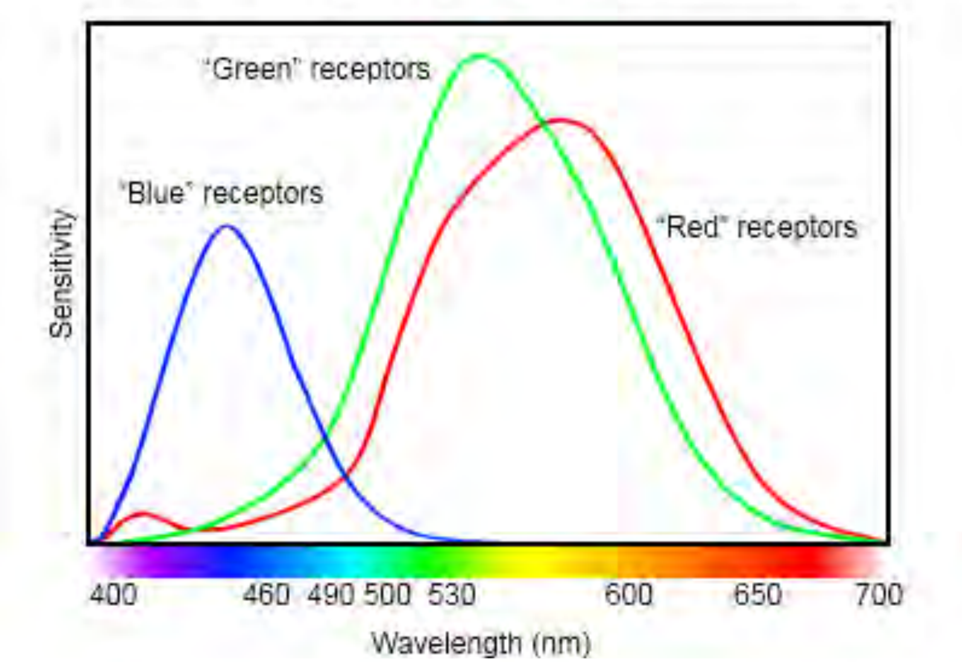
Grade		Base colour of fruit	Colour of remaining fruit
LIGHT	6CL	Bold, bright amber colour	5% dark berries
	5CL	Light amber colour	10% dark berries
	4CL	Average amber colour	15% dark berries
	3CL	Amber to light brown	20% dark berries
	2CL / standard	Light brown	50% dark berries
DARK	5CB	Dark amber colour	10% dark brown berries
	4CB	Dark amber to brown	15% dark brown berries
	3CB	Uniform brown	20% dark brown berries
	2CB / standard	Uniform dark brown	N/A

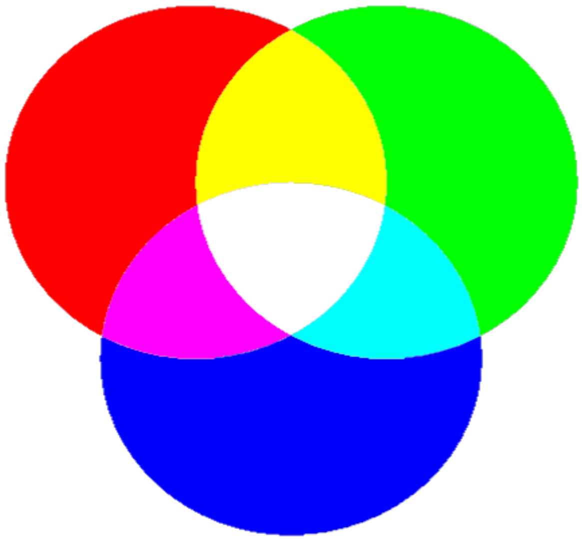

4 crown light

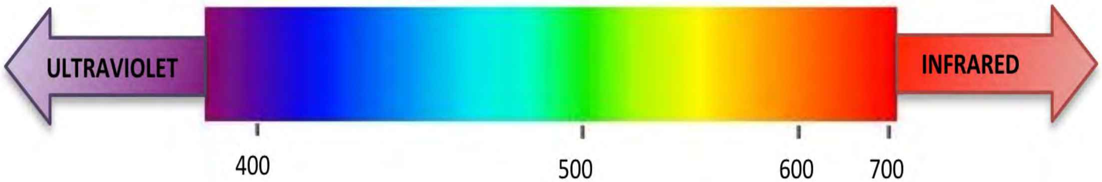

3 crown light

What is colour?

- Colour is reflected wavelengths of electromagnetic energy
  - Intercepted by different colour receptors on the eye

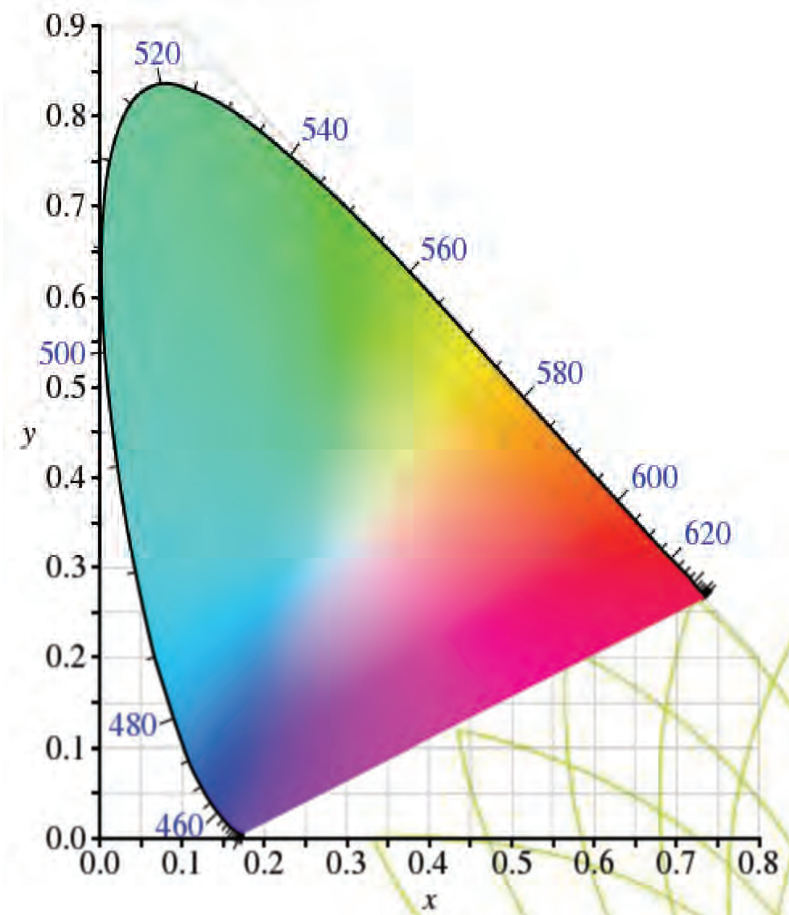






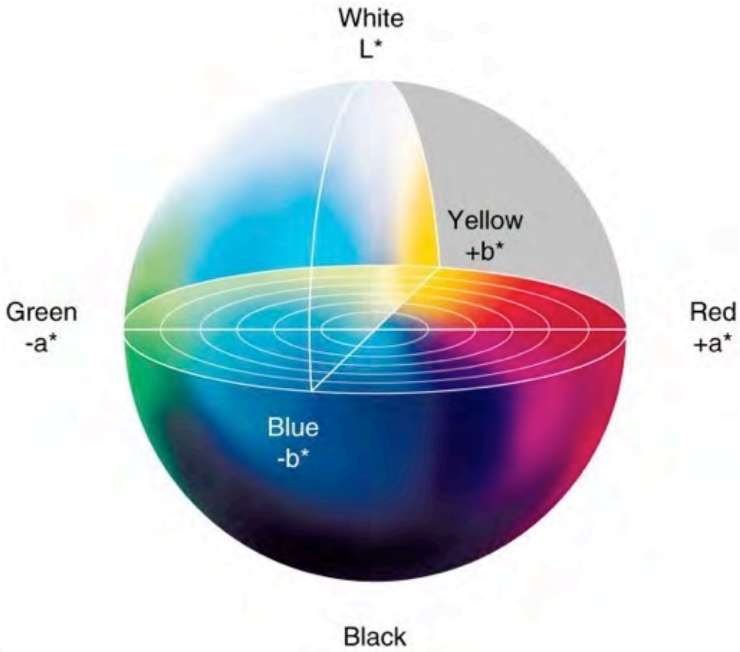
Colour into numbers

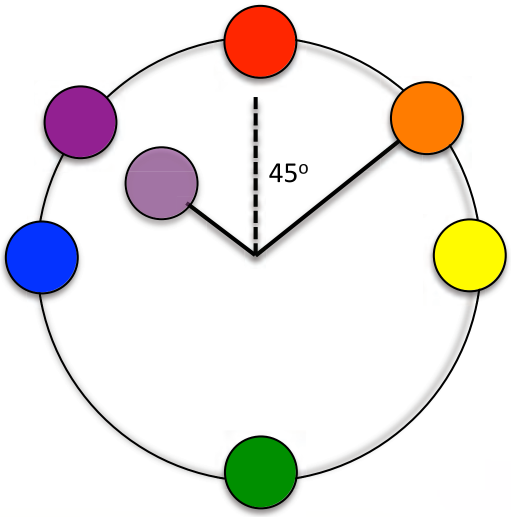
- Lots of different systems for measuring colour
  - RGB – Red, green, blue; used for screens and monitors
  - CMYK – Cyan, magenta, yellow, key; used for printing
  - CIE XYZ – approximates the responses of the red (X), green (Y) and blue (Z) cells in the eye; *tristimulus* values that encompass everything a normal person can see



Colour into numbers

- Hunter Lab – developed for electromagenetic measurements
- CIE L*a*b* – superceded the Hunter system, derived from XYZ but in a system more easily understood
- Adobe Lab – similar system to CIE, but numbers are different



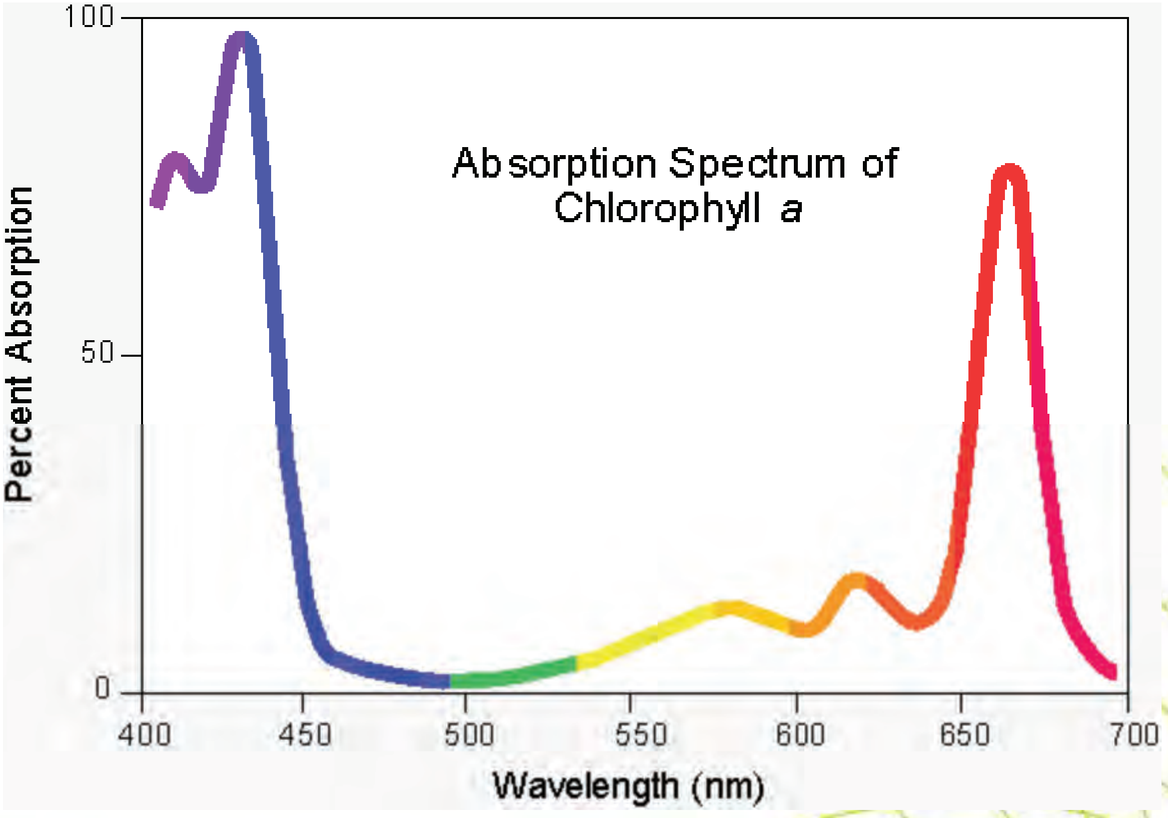


Colorimeters

- Three components
    1. A standard source of light
    2. A combination of filters
    3. A photoelectric detector that converts reflected light into optical output.

Spectrophotometers

- Measure absorbance / reflectance of the whole spectrum
  - Visible light
  - Ultraviolet
  - infrared

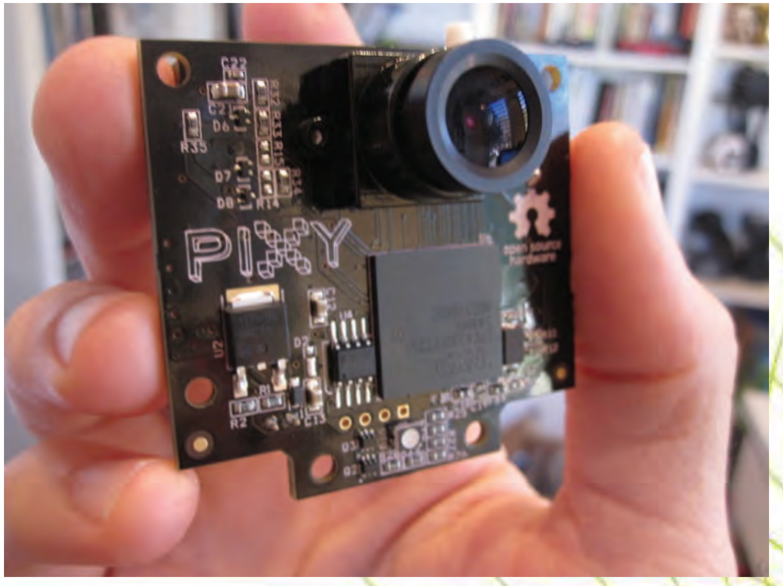


Spectrophotometers

- Used to be large and laboratory based, but now increasingly miniaturised
- Used to measure many things – colour, sugars, moisture, acids content, chlorophyll…….

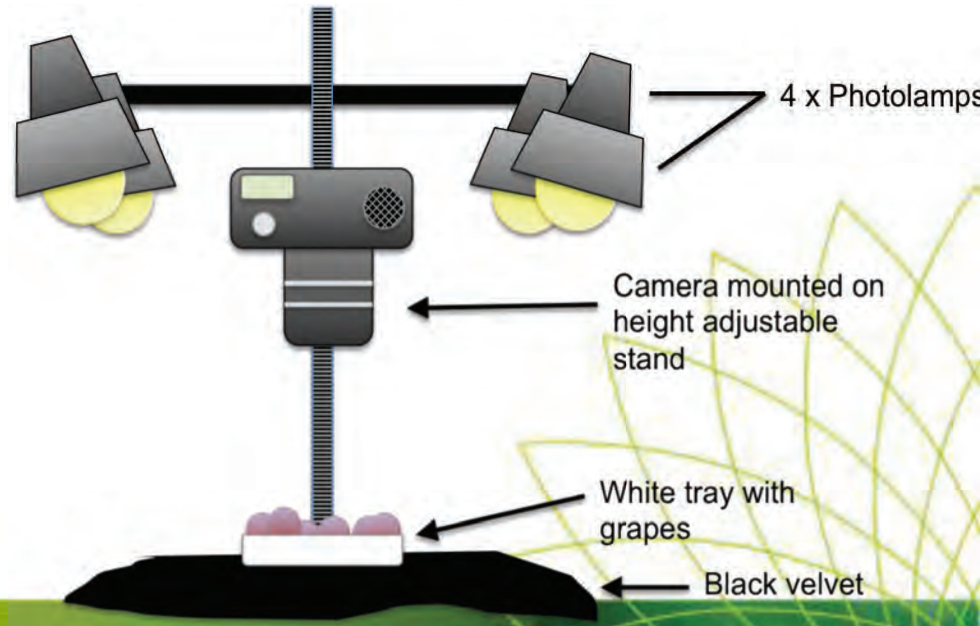
Photography

- Digital cameras not limited by area, surface texture, curves…
- High resolution images even with mobile phones
- Computer vision systems (CVS) already widely used, including for sultanas



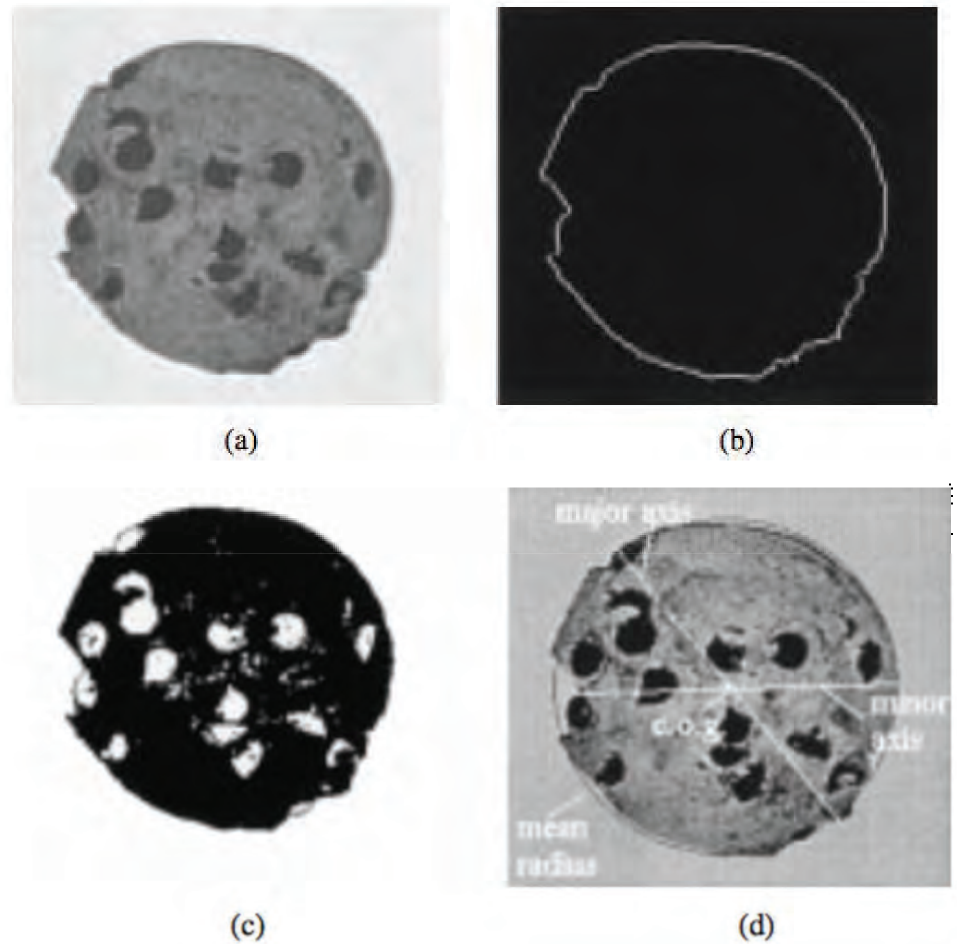
Photography

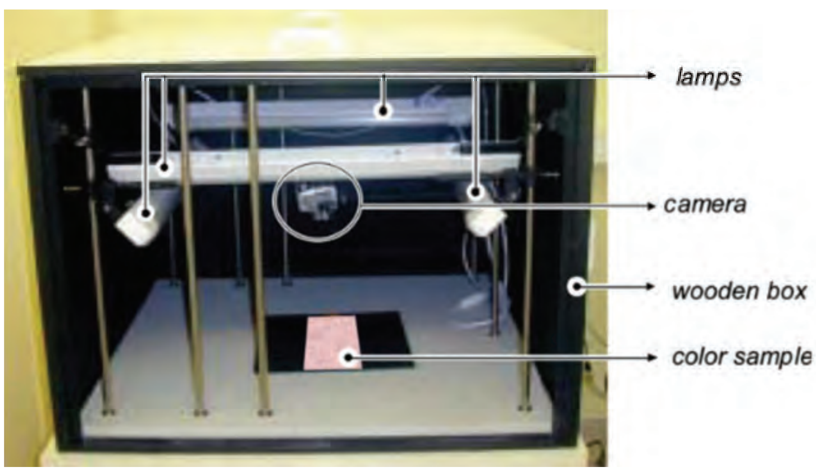
- Critical factors
  - Exposure, as digital cameras automatically adjust
  - Lighting - need to simulate daylight, 45° angle
  - Avoid shadows, uniform intensity across sample
  - Conversion of RGB to Lab colour space



What others have done

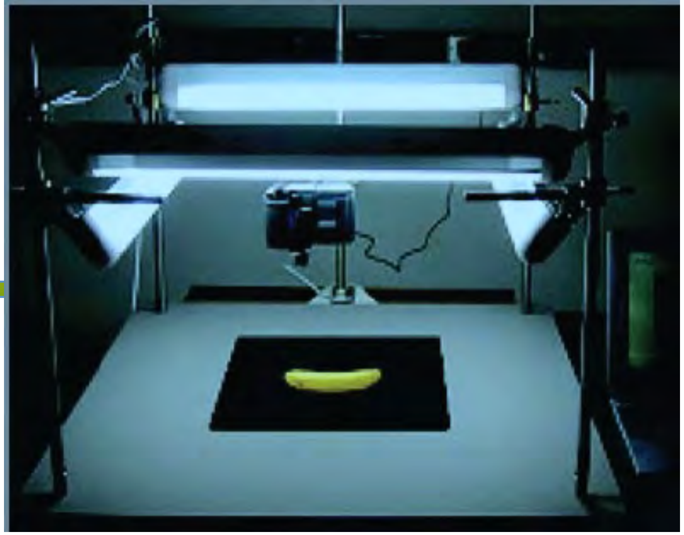
- Davidson VJ, Ryks J,Chu T. 2001. *Fuzzy models to predict consumer ratings for biscuits based on digital image features.*

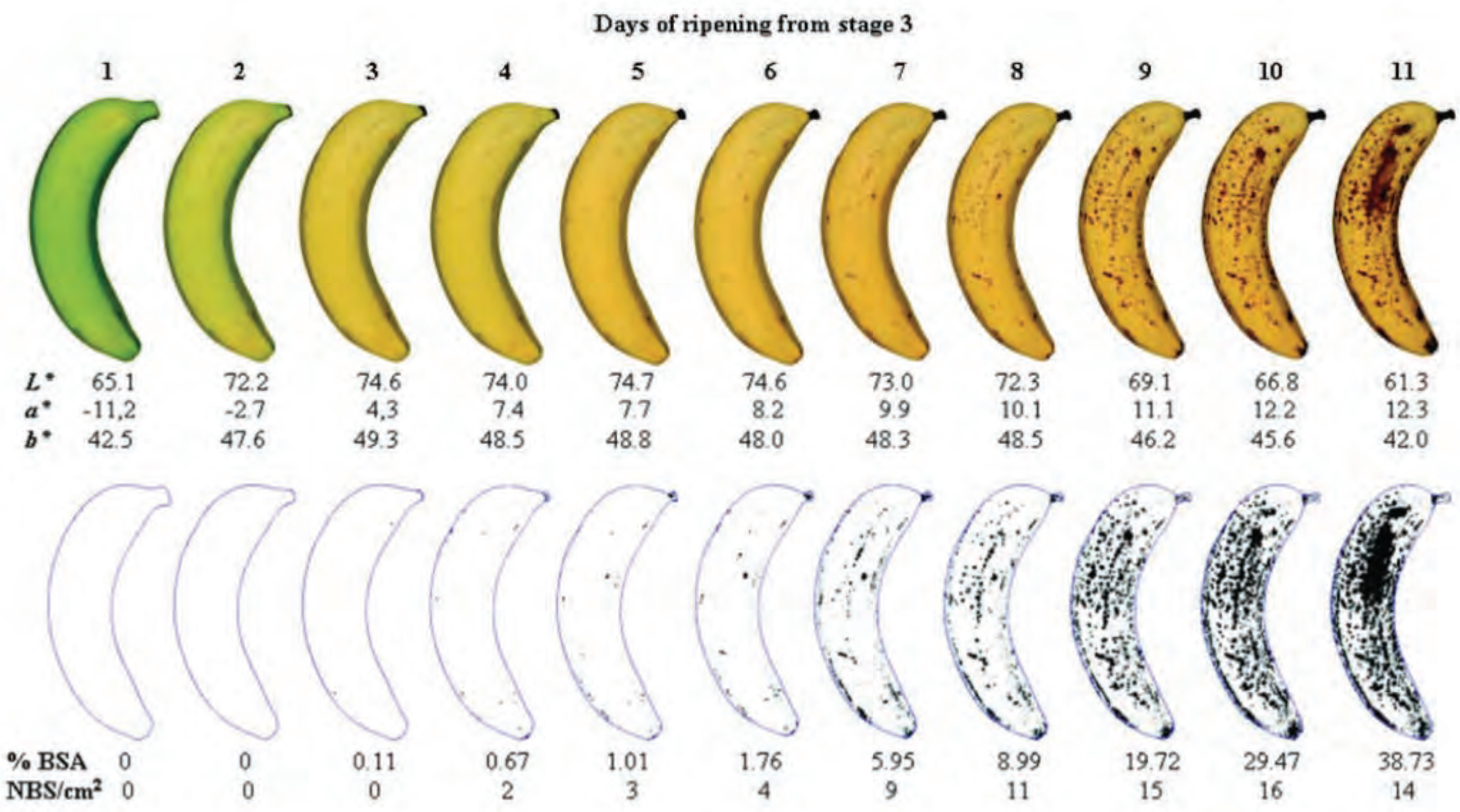




What others have done

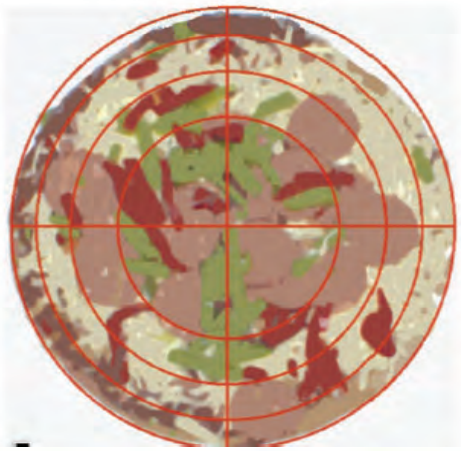
- Mendoza F Aguilera JM. 2004. *Application of image analysis for classification of ripening bananas*

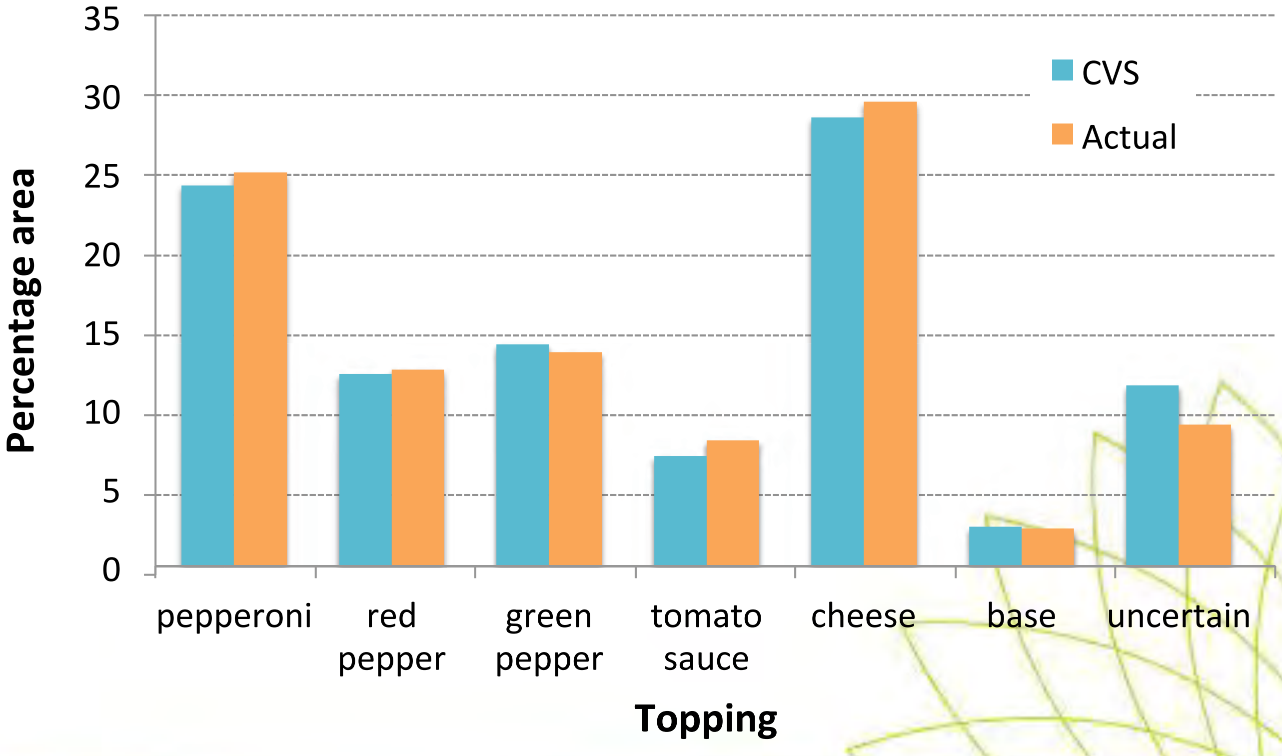




What others have done

- Sun D-W. 2000. *Inspecting pizza topping percentage and distribution by a computer vision method*

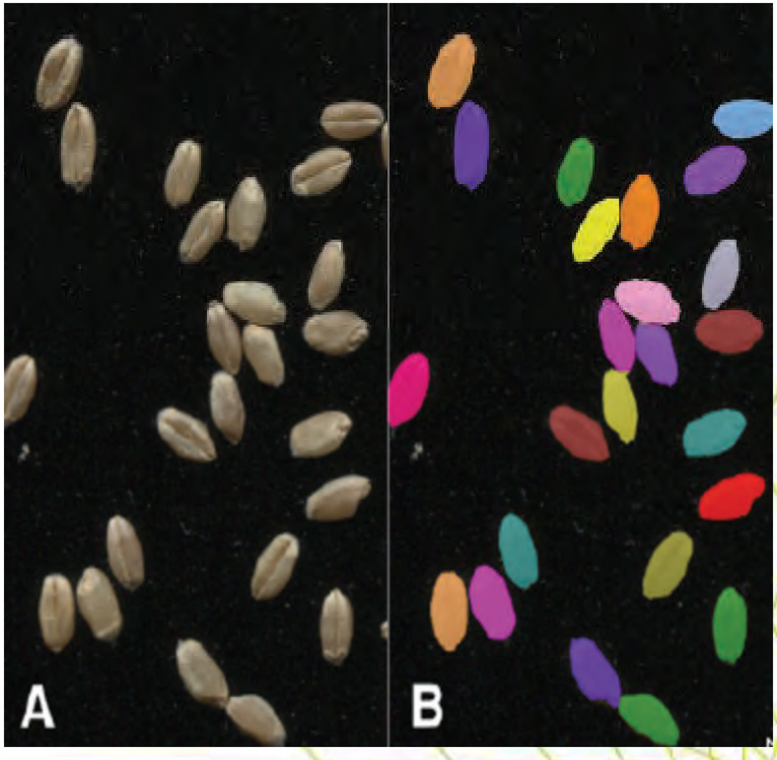




What others have done

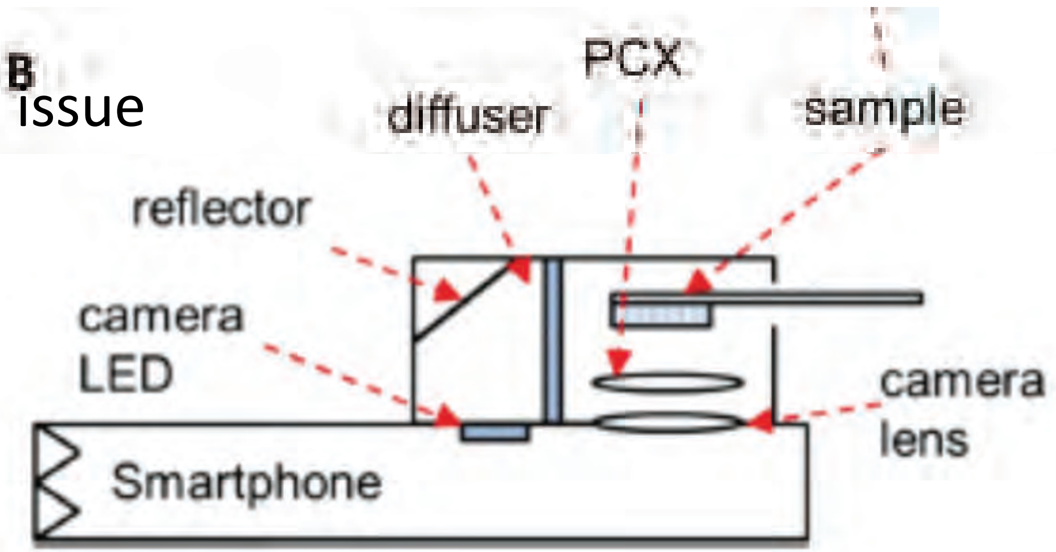
- Flatbed scanners – used for wheat, lentils, canola
  - GrainScan - Whan AP et al. 2014. *GrainScan: a low cost, fast method for grain size and colour measurements*

"Colour is what I was particularly interested in when we developed GrainScan … I would expect it to be able to work (for dried fruit). It would certainly be the lowest cost option I know of."



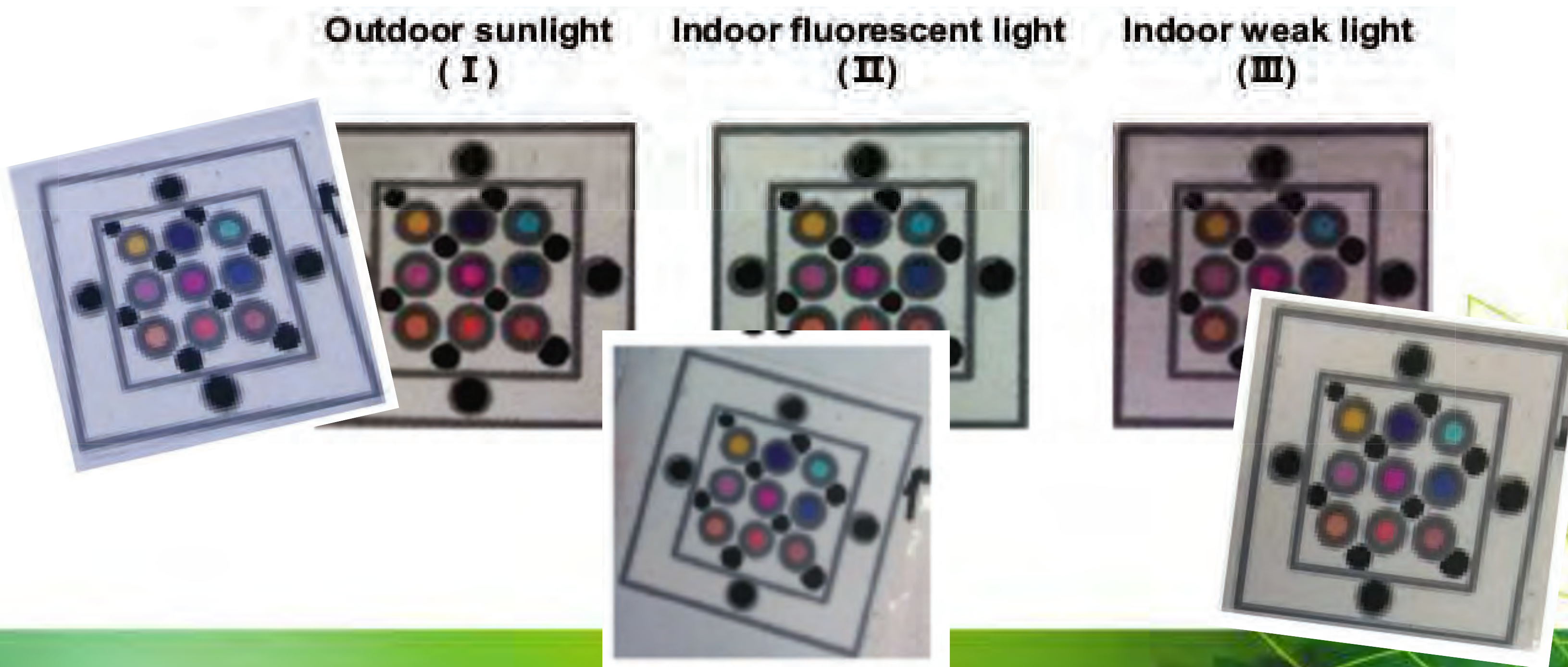
Smartphones

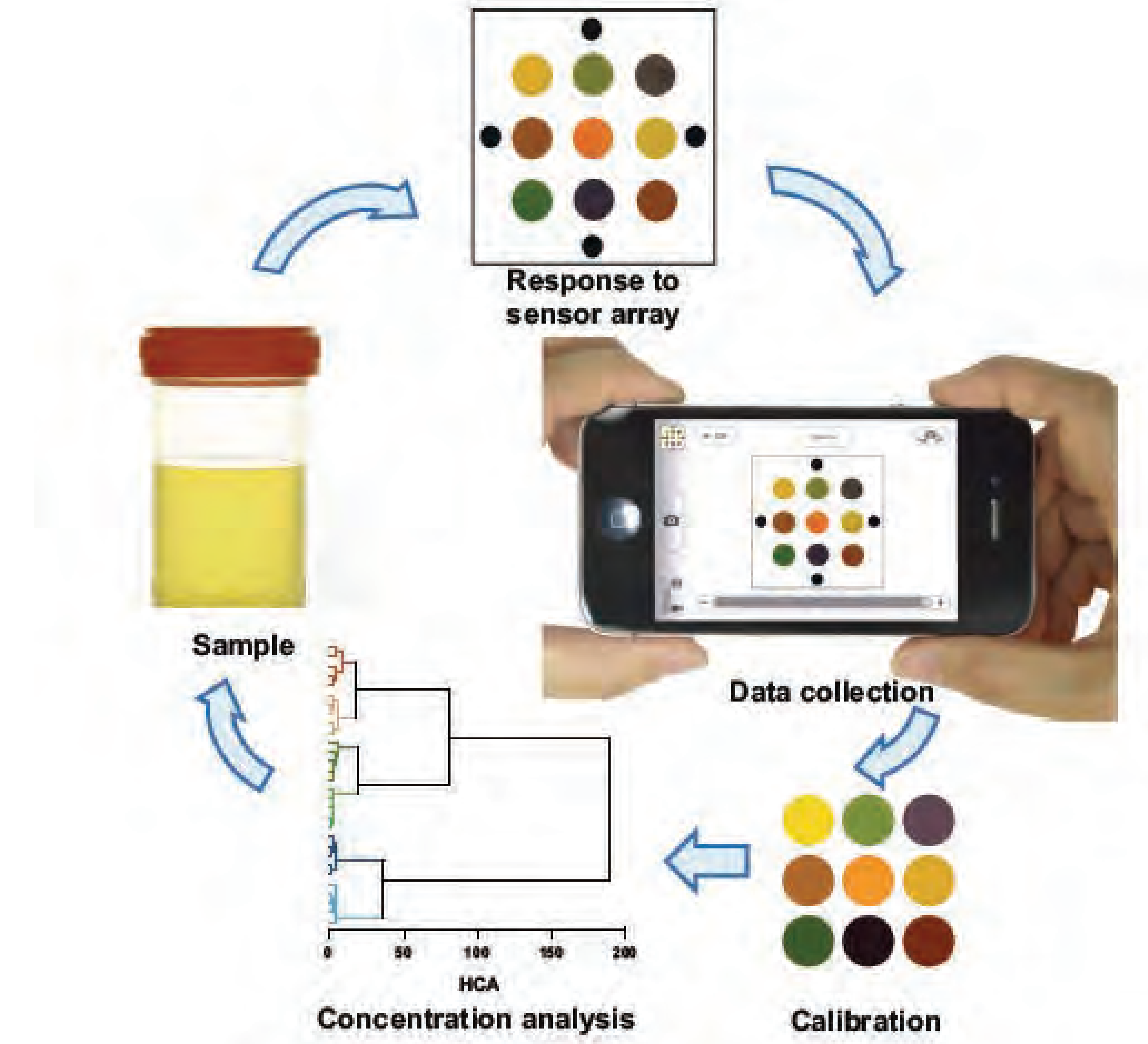
- Most research on medical applications, simple colorimetric tests;
  - Poo colour (PoopMD)
  - Glucose in urine
  - Alcohol in saliva
- Calibration remains an issue



Smartphones

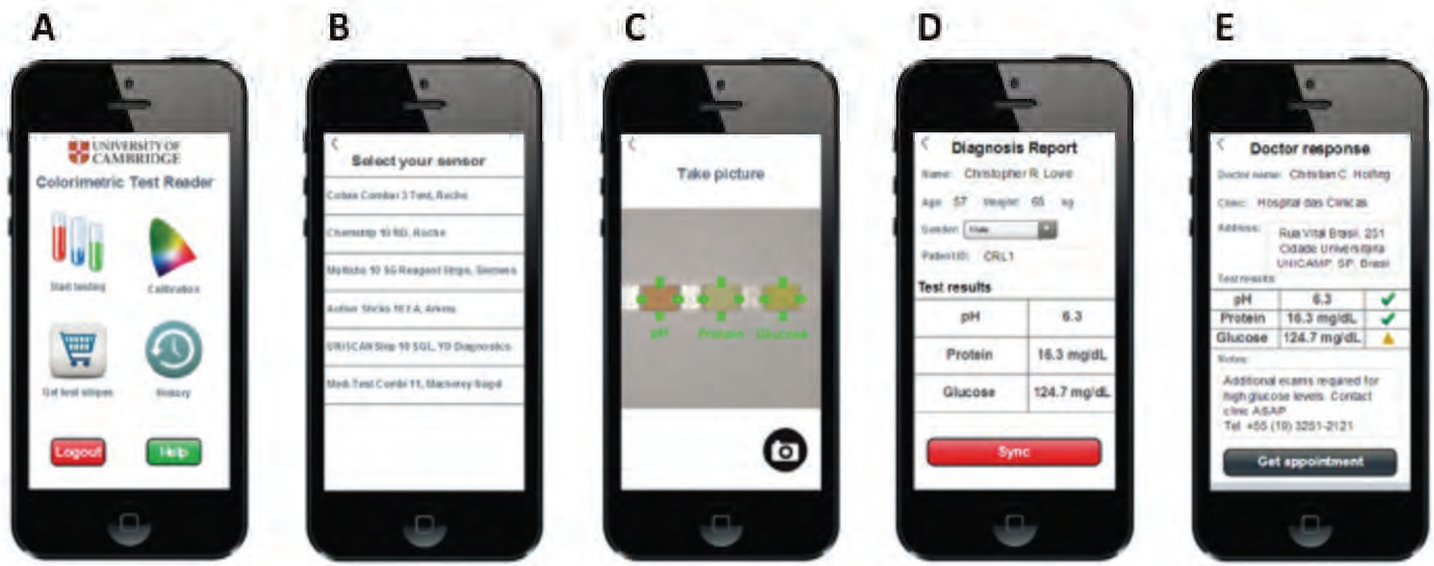
- Tiles used to calibrate device using white, black, angle
  - Jia M-Y et al. 2015. *The calibration of cellphone camera-based colorimetric sensor array and its application in the determination of glucose in urine.*




Response to sensor array
Data collection
Calibration
0
50
100
150
200
HCA
Concentration analysis
Sample

Smartphones

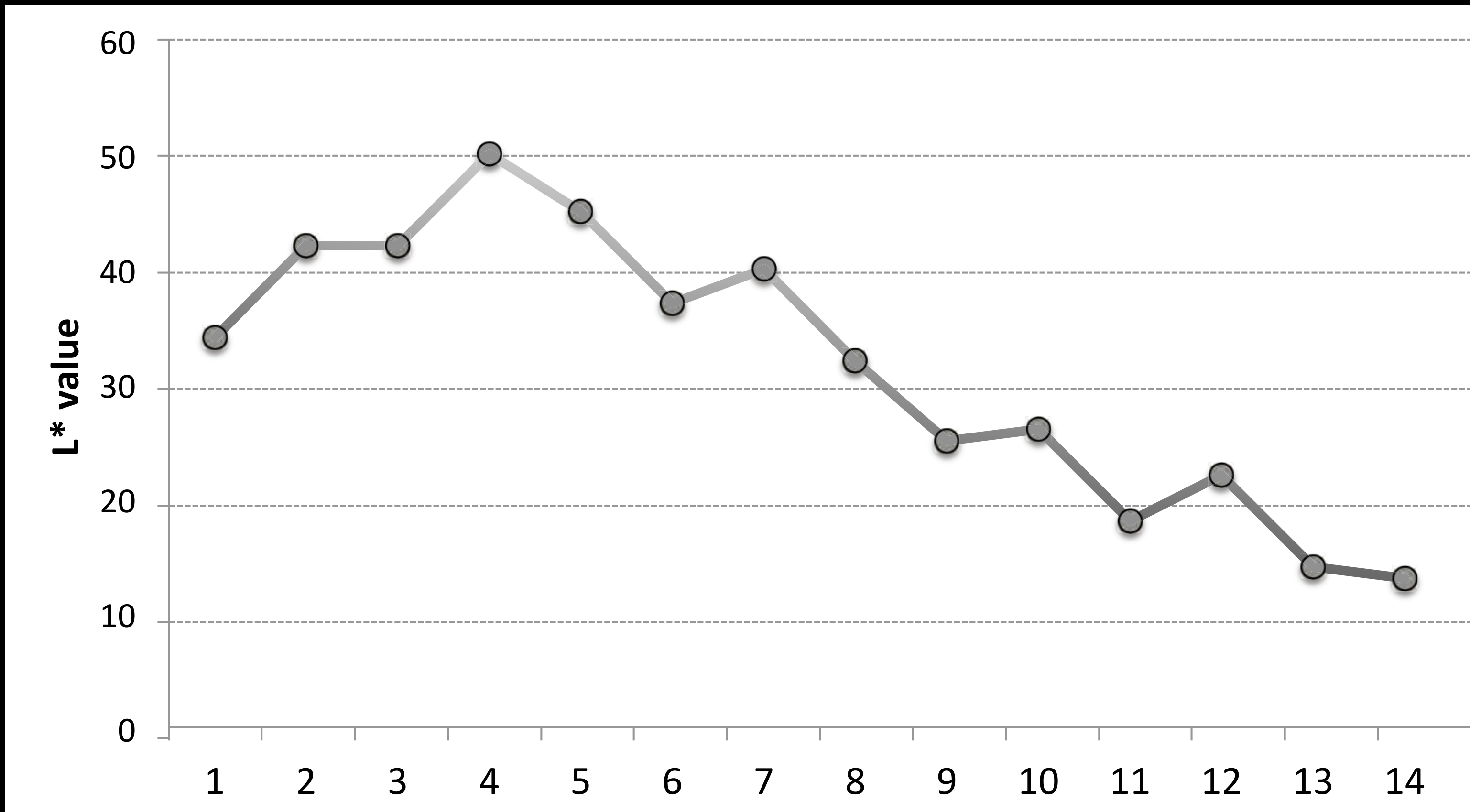
- App developed by Cambridge University
  - Yetisen AK et al. 2014. *A smartphone algorithm with inter-phone repeatability for the analysis of colorimetric tests*.
  - A-Main menu, B-Sensor types, C-Image of the test strip, D-Diagnostic test results, E-User instructions



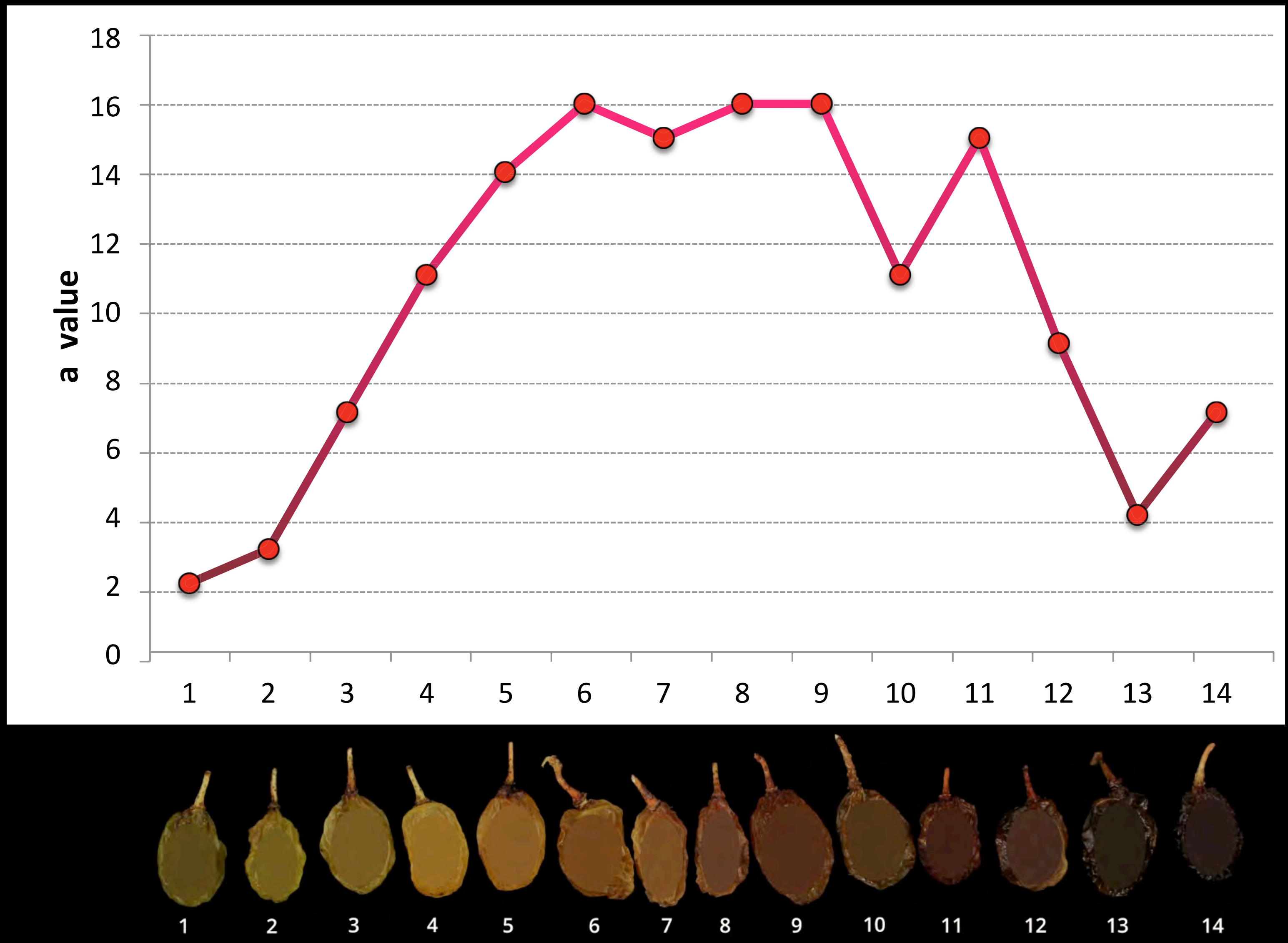
But what of sultanas?

- Delimiters….. Use Photoshop?

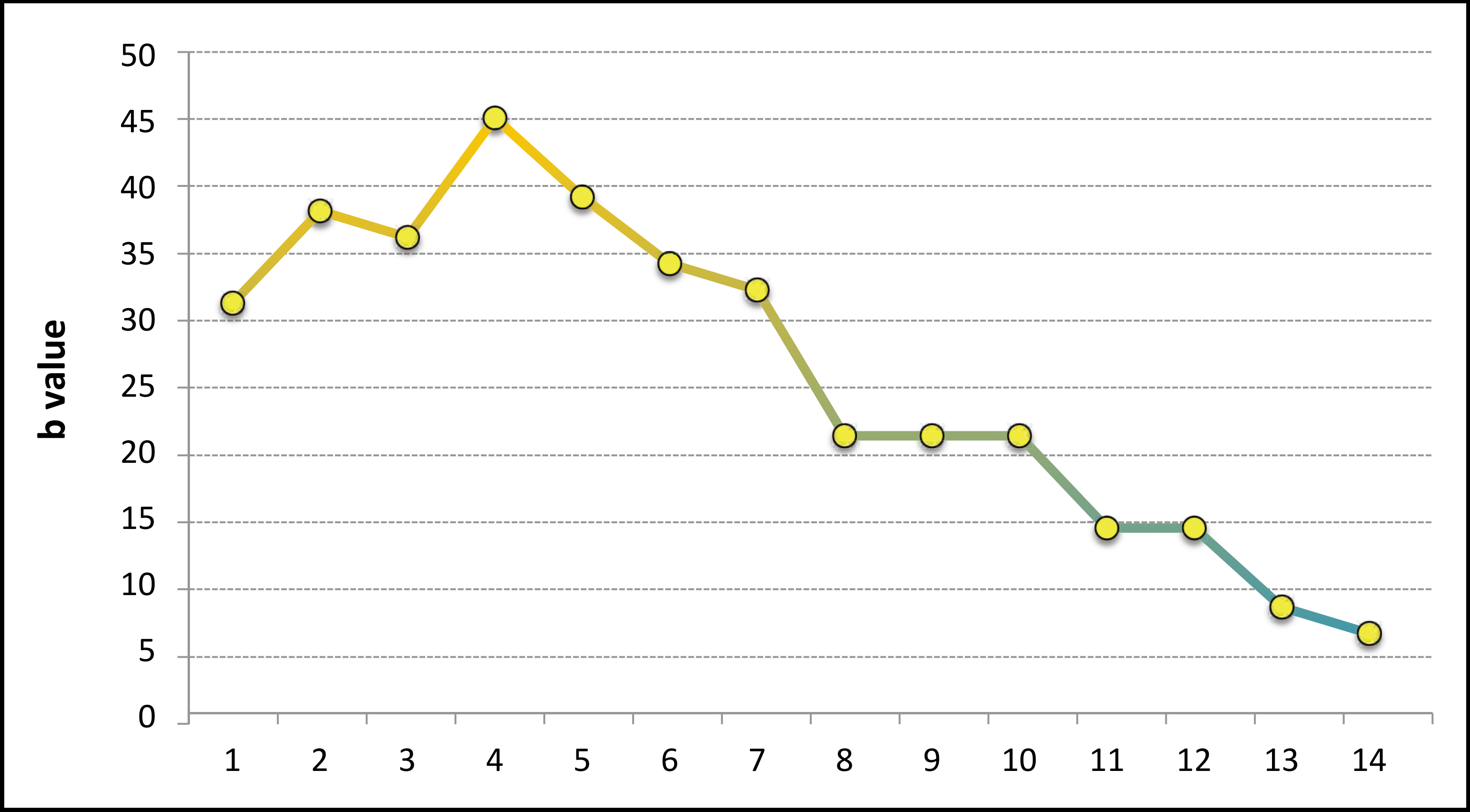
Sultana colours

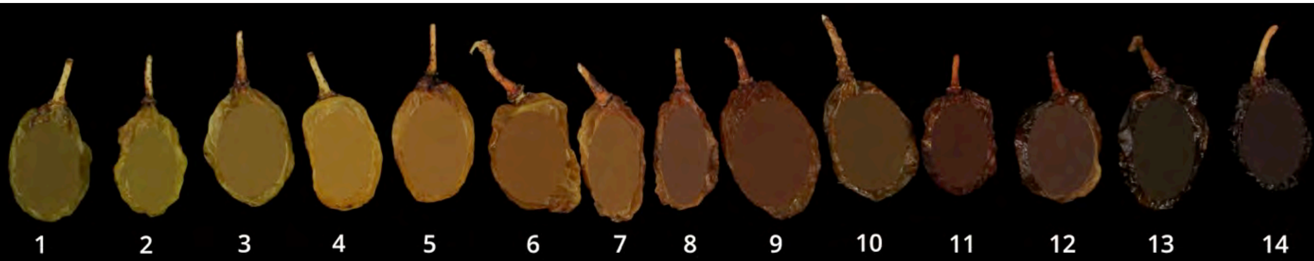


Sultana colours

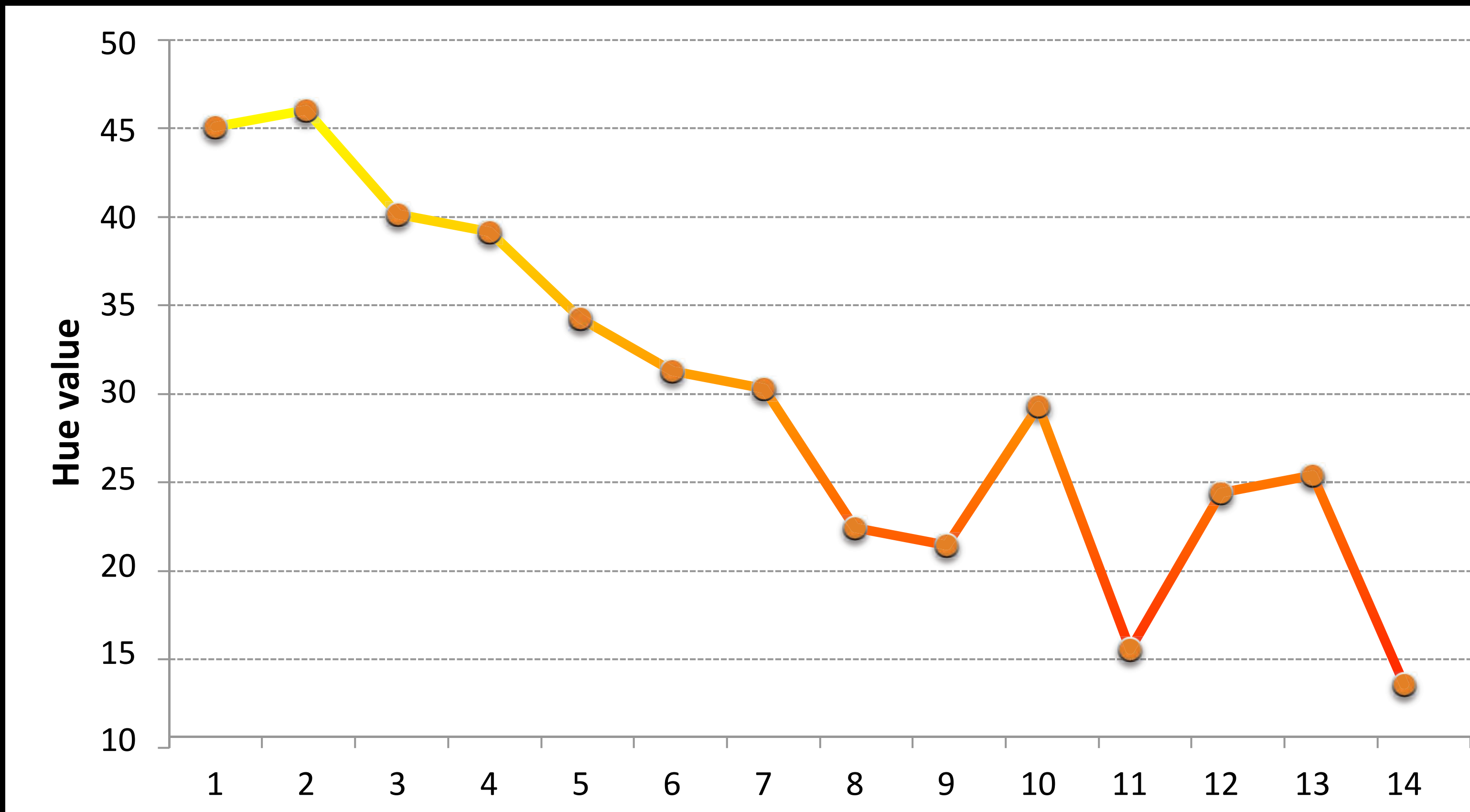


Sultana colours

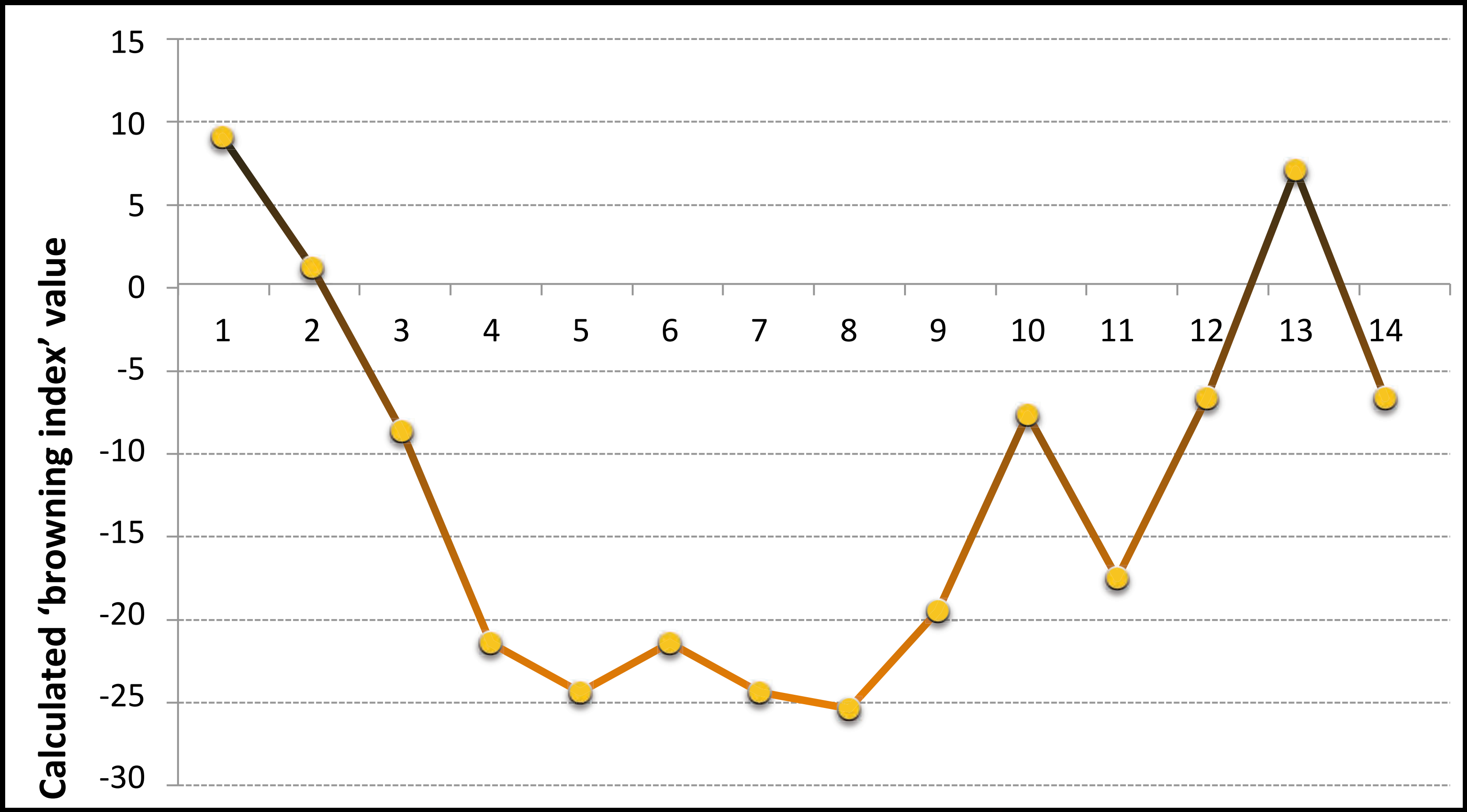




Sultana colours



Sultana colours



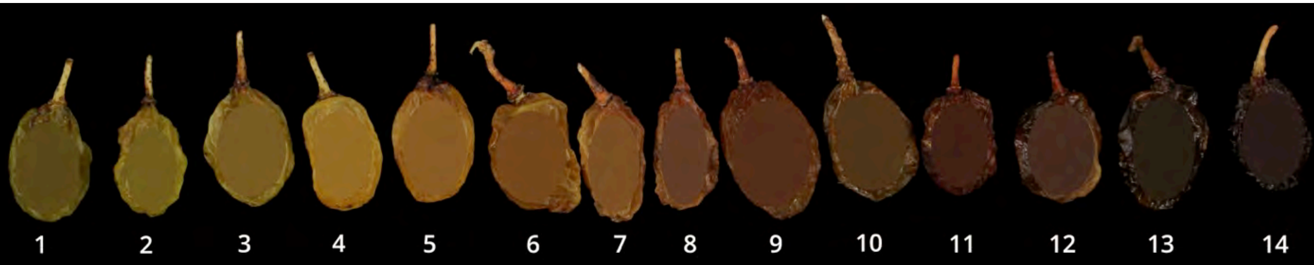
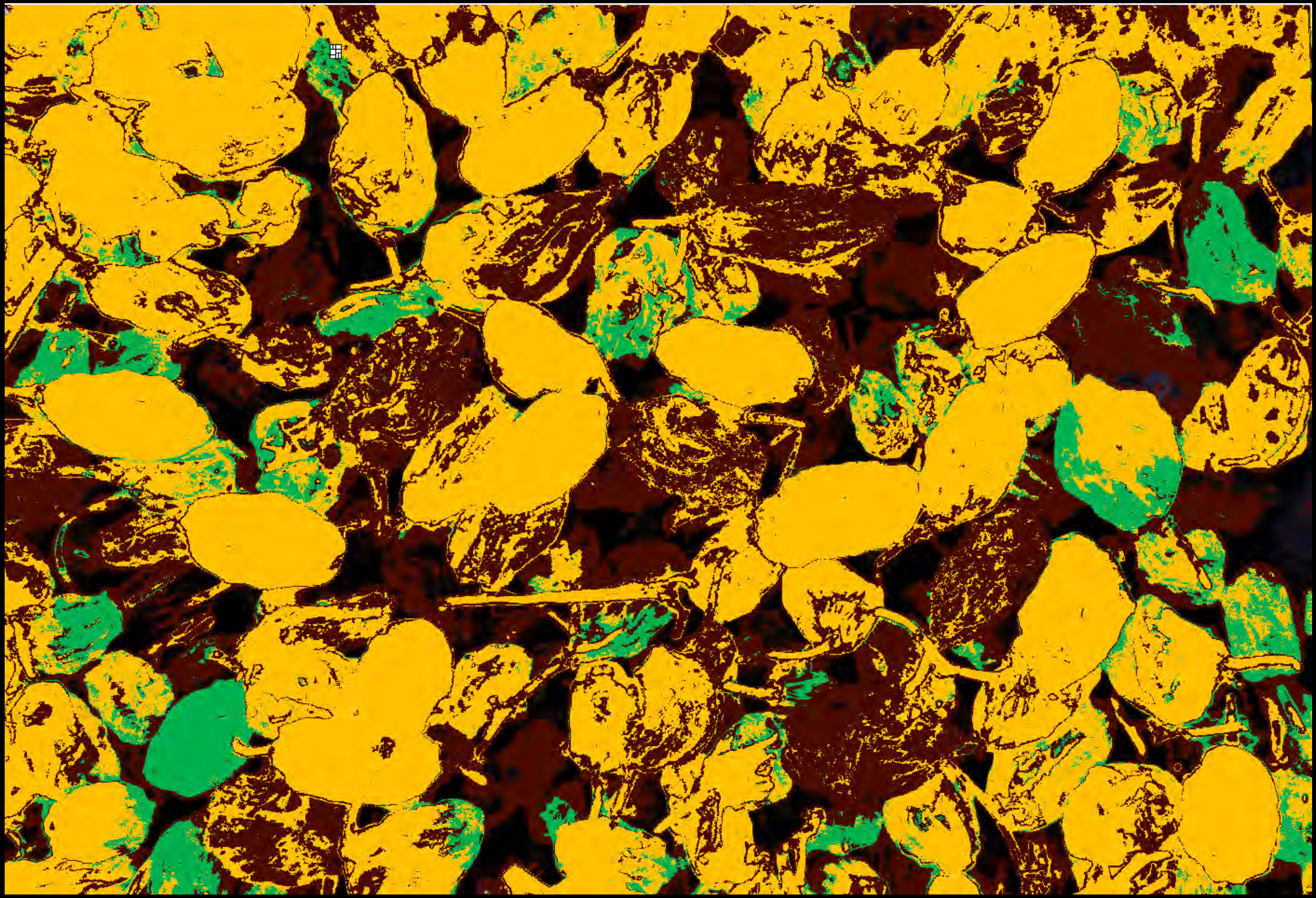


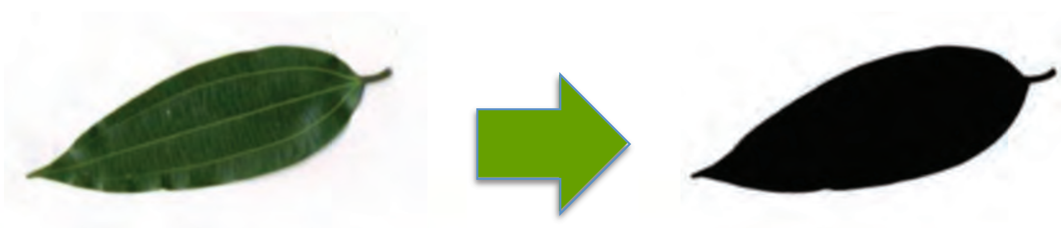
Image analysis - Photoshop

Image analysis - ImagePro



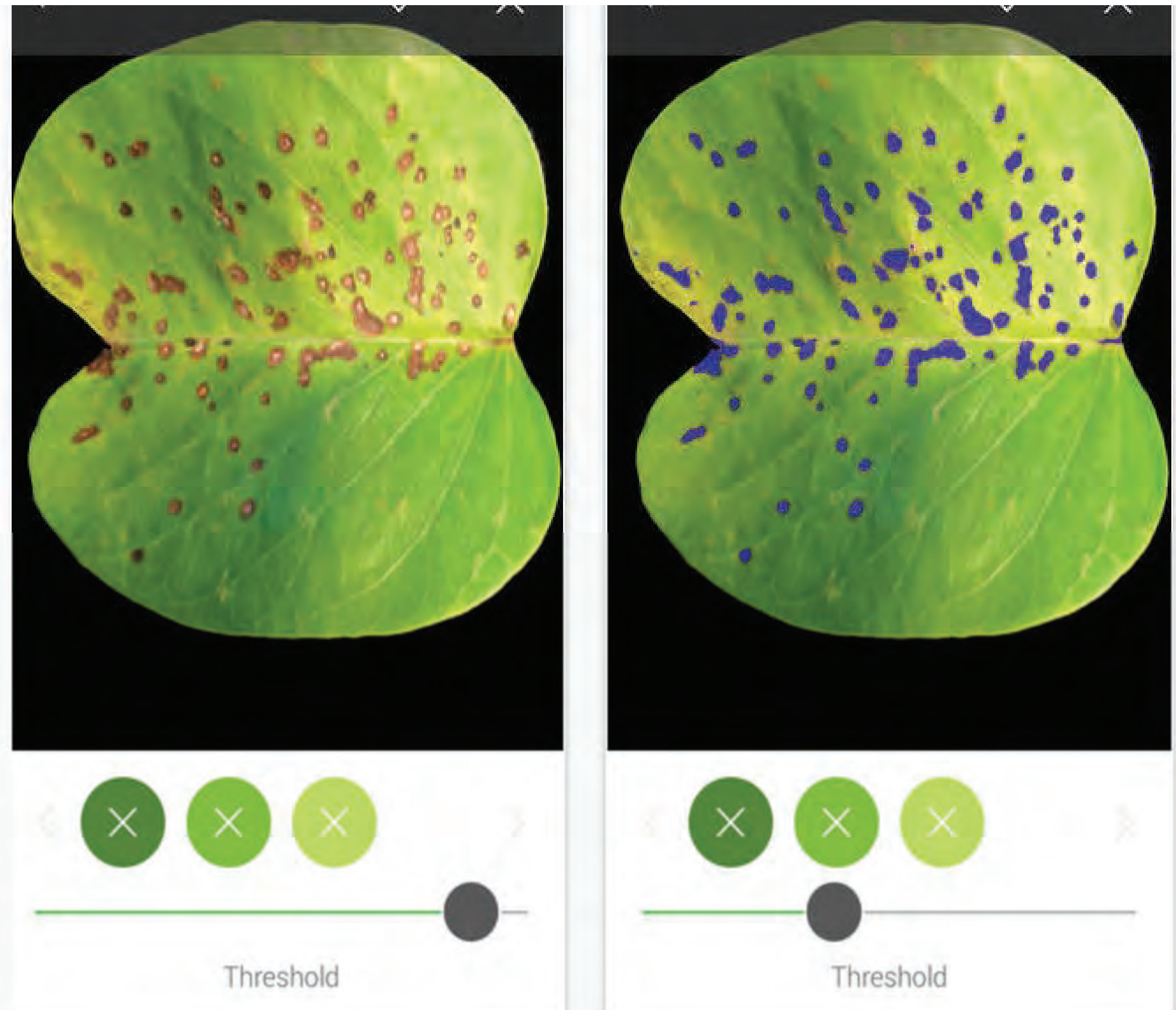
Existing programs that do this (kind-of)

- Easy leaf area, Black spot



Existing apps that do this (kind-of)

- Leaf Doctor



Next steps?

- Test whether sultanas can be adequately imaged using a flatbed scanner
- Record images of all possible grades of sultanas on black / white backgrounds as well as in bulk bin style.
- Record images of individual sultanas as guides to critical limits for light / brown fruit as well as dark berries
- Process images using Photoshop / ImagePro and Minolta chromameter to analyse colour in L*a*b* colour space
- Together with industry, determine colour delimiters……

Maybe also…

- Develop a prototype photographic box system for smartphone or tablet
  - Daylight illuminants (~6500K)
  - Light angle to product set at 45°, even lighting over full product surface
- Discuss pictures and delimiter values with software designers
  - Determine likely cost of developing a bespoke program
  - Determine best way of presenting images for analysis
- Test different methods of analysis
  - Could an average value plus measure of sample variability achieve the same end result??


Thankyou !

DG15001 Objective colour assessment of dried grapes

Trial results

1. 1. Defining colour of sultanas

1.1. Aim

To define the delimiting colour values for different grades of dried sultanas.

1.2. Method

Sultanas were divided into groups based on colour. Nine different groupings were identified, with at least 10 individual sultanas within each group. These were described as;

1	2	3	4	5	6	7	8	9
Greenish	Gold	Lt amber	Amber	Dk amber	Lt brown	Brown	Dk brown	Blackish

The 10 sultanas visually judged to be closest in colour within each cohort were measured using a Minolta chromameter, with values output as L*, a* and b*.

Each group was then photographed on a black background using daylight globes arranged to minimise shadows around each berry. A piece of white filter paper was included in each photograph to provide a white reference.

Photographs were analysed using Adobe Photoshop. After white and black balance adjustment, each sultana was individually selected and central area averaged. The colour of this area was recorded as R, G, B as well as the Adobe values for Hue, L, a and b.

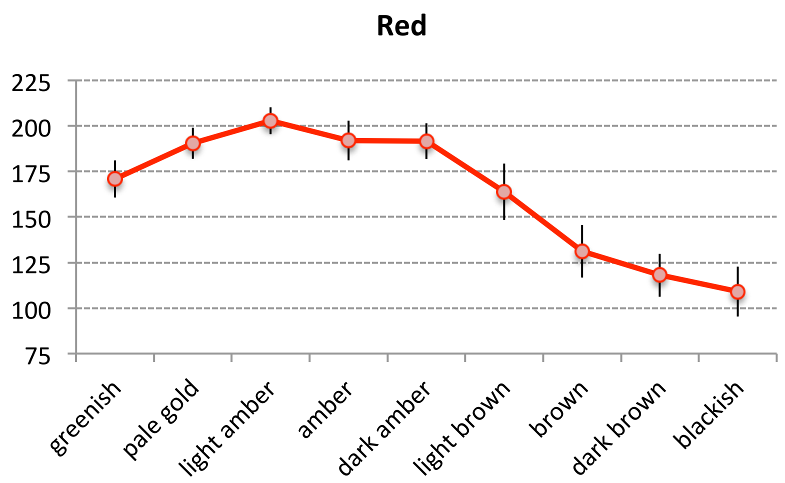
1.3. Results

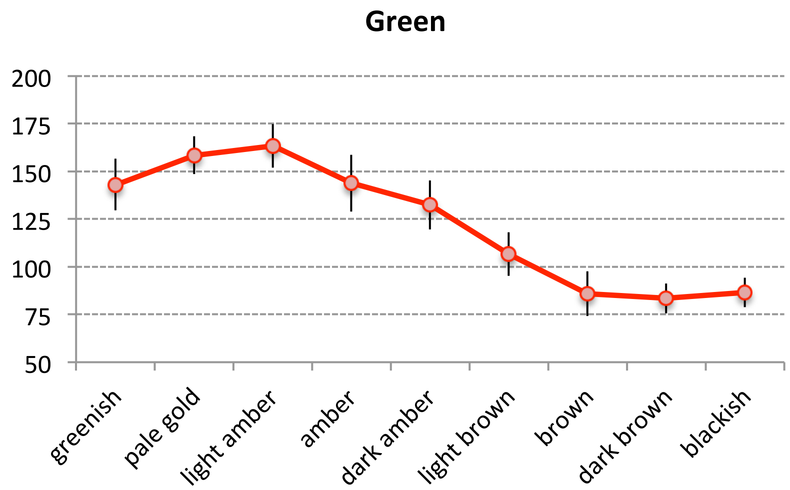
The average colour of each group of sultanas was calculated from the values generated by Adobe, as well as those recorded by the Minolta colorimeter.

Table 1 - Mean colour values for different cohorts of sultanas, calculated using Adobe Photoshop

	R	G	B	Hue	L	a	b
Greenish	170.9	143.1	63.4	44.2	60.9	4.1	45.3
Gold	190.4	158.4	72.7	43.9	66.9	4.9	48.1
Light amber	202.7	163.3	84	40.2	69.6	8.3	46.2
Amber	192	143.8	68.8	36.3	63.2	13.3	46.1
Dark amber	191.6	132.4	67.5	31.3	60.5	18.8	43.8
Light brown	163.8	106.6	70.8	23	50.6	20.6	29.9
Brown	131.1	85.9	67.5	17.3	41.4	17.5	18.9
Dark brown	118	83.5	70.9	16	39	13.7	13.4
Blackish	109.1	86.6	74.6	21.3	38.8	8.1	10.7

Colour is recorded by the digital camera, and manipulated and displayed by Photoshop, in the RGB (red, green, blue) colour space. As shown in Figure 1, the values for blue did not differentiate between the different colours of sultanas. However, the values for red showed a distinct decline as sultanas changed from amber to brown. Values for green declined sooner, with significant changes occurring between light and dark amber.





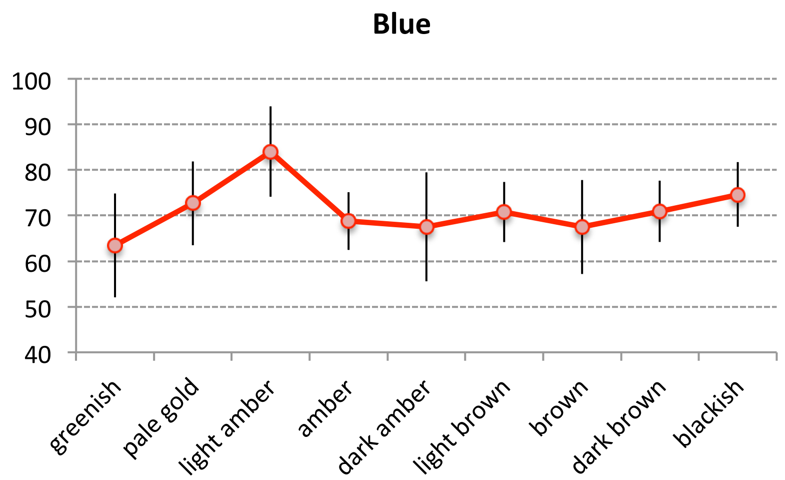


Figure 1 - RGB values for different colours of sultanas, calculated using Adobe Photoshop. Bars indicate the standard deviation of each mean value (n=10)

The L a b values reported for a particular colour by Photoshop are numerically different to those reported using a Minolta colorimeter. Despite this, they show an extremely close correlation in terms of the relative changes in recorded values between different cohorts (Figure 2). Variability among the measurements was also similar.

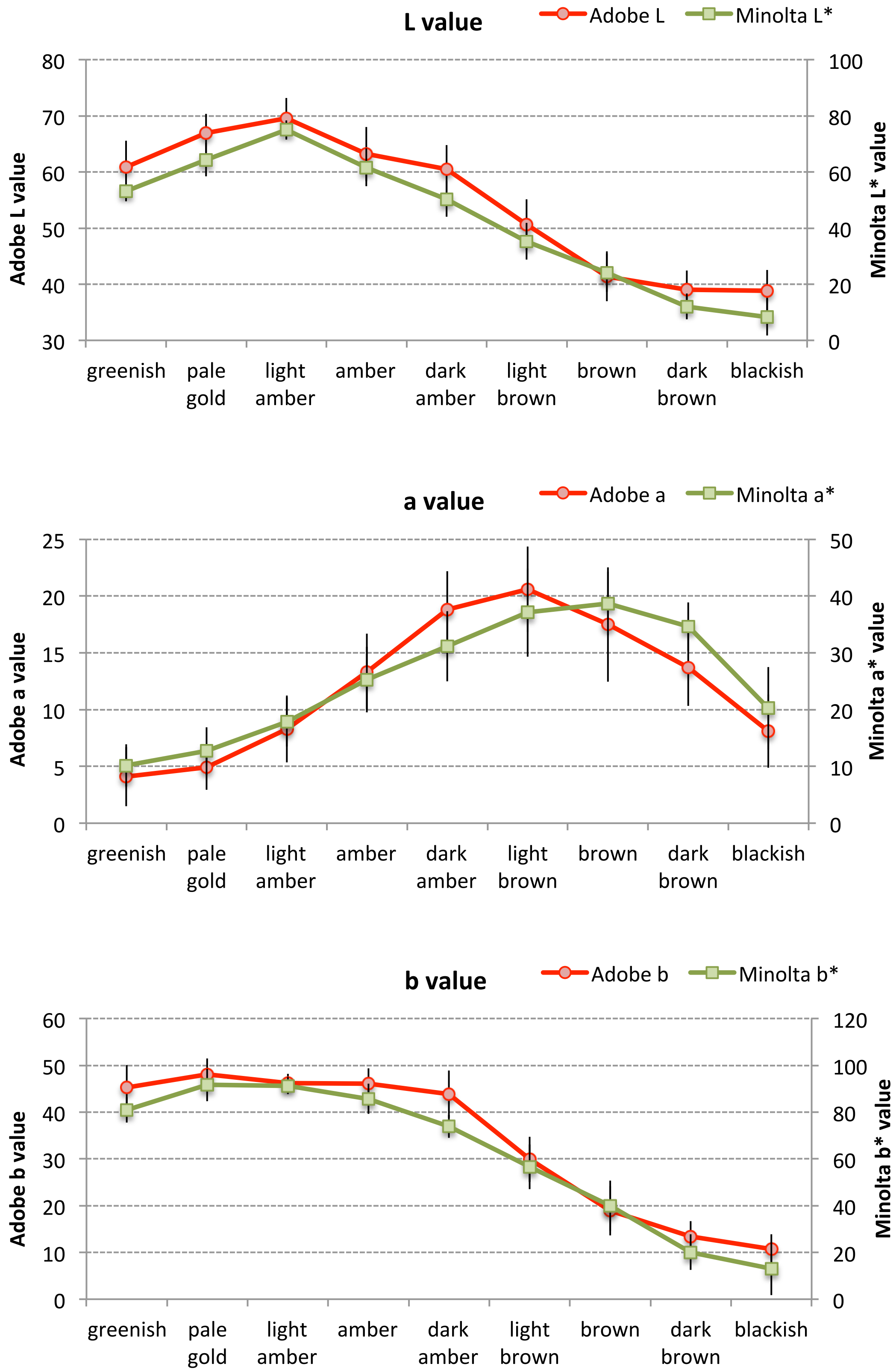


Figure 2 - L, a and b values for different colours of sultanas, calculated from photographs using Adobe Photoshop, compared to analysis of the same fruit using a Minolta colorimeter. Bars indicate the standard deviation of each mean value (n=10).

Values for a and b can be integrated by calculating the Hue angle. As shown in Figure 3 this provides an excellent discrimination between the different sultana colours, with reduced variability overall.

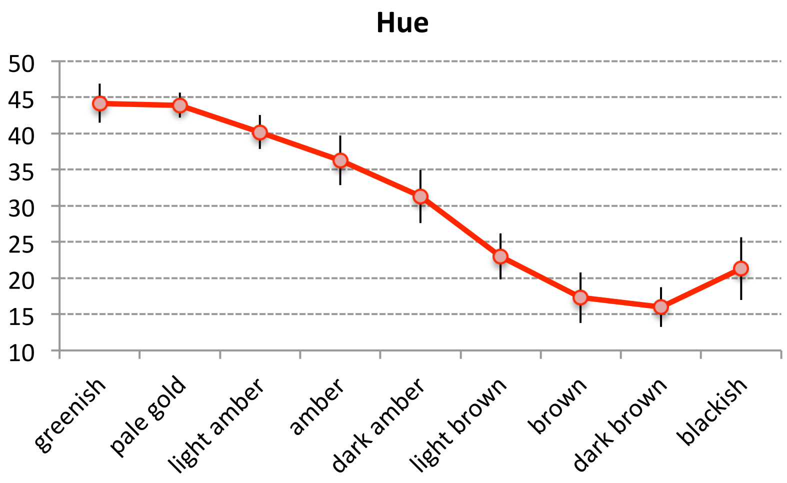


Figure 3 - Hue values for different colours of sultanas, calculated from photographs using Adobe Photoshop. Bars indicate the standard deviation of each mean value (n=10).

The values shown in Table 1 can be used to generate actual mean colours, which can be output as a swatch (Figure 4).

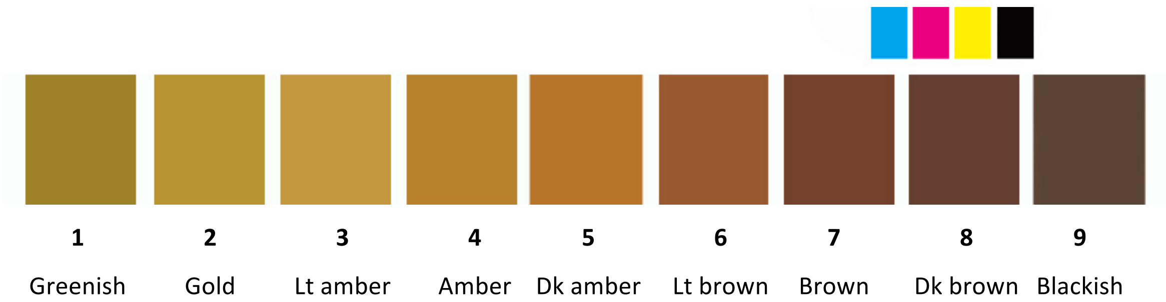


Figure 4 - Colour swatches, based on mean colour values for different colours of sultanas. A CMYK reference is included for printing purposes.

1.4. Discussion

This activity has generated a series of mean values representing different shades of colour of dried sultanas.

These values may be used to categorise fruit as either LIGHT or DARK, based on the ground colour of the majority of the fruit within the batch. The most appropriate value to use will depend on the delimiting value chosen.

The limits of these values need to be determined by the industry. For example, it may be decided that 1 to 5 = LIGHT, 6 to 9 = DARK.

The data collected so far suggests it will be more difficult to differentiate fruit based on green tinge. Most of the values recorded for 1 (greenish) are either similar to those for 2 (gold) or overlap significantly with those for 4 (amber). Differentiating these fruit will require a combination of values. For example,

IF RED < 175 and GREEN > 125 then fruit is 'green tinge'

If Adobe L < 65 and HUE > 40 then fruit is 'green tinge'

Note that both of these criteria may classify some fruit that was visually classified as 2 (gold) as 1 (green tinge). Sunbeam classifies fruit with green tinge as brown, as this fruit will darken under ambient storage conditions. However, APDF do not classify fruit this way, possibly as browning is reduced under refrigerated storage.

If green tinge is considered to be important for classifying fruit, then additional sampling may be required to further refine these values.

Fruit grades

The current grading system is extremely complex, dividing fruit as it does according to both base colour and variability (percentage dark fruit) within the batch. Simplifying this system would seem to have major advantages, as it would reduce disputes as well as simplify the development of an objective assessment method.

Based on 2016 prices, both processors effectively have four grades for sultanas. However, how they divide the stock between these grades varies significantly. Both do not differentiate between Brown 4 and 5 crown fruit. However, whereas APDF also does not differentiate between Light 4 and 5 crown, Sunbeam does differentiate these grades.

Even if it is assumed that virtually no fruit is ever graded as Light 6 (export gold), then 5 grades are still needed to accommodate the range in prices paid for dried fruit. There therefore appears to be little opportunity to reduce the complexity of the current system.

Table 2 - Grades of fruit, categorised according to approximate 2016 prices paid by the processors

Base colour	Variability (crown)	Sunbeam	APDF
Light	6	N/A	
	5		
	4		
	3		
Brown	5		
	4		
	3		

2. Defining sultana colour grades

2.1. Aim

To compare the dried grape industry sultana colour grading system with visual grading using a colour scale.

2.2. Method

Sultana samples with colour grades already assigned by APDF or Sunbeam were collected in Mildura and taken back to Sydney. A sub-sample of ~50g (~100-150 sultanas) was taken from each of 3 samples from six different colour grades.

Samples were assessed in a light box setup (Figure 5) with a Crompton natural daylight (6500K) fluorescent light. Sultanas were separated into a base colour, as well as other remaining colours. Colour of the segregated berries was determined using a colour scale (Figure 6). Dishes were weighed to determine the proportion of sultanas in each colour category.

Figure 5. Light box setup for assessing colour of sultana colour

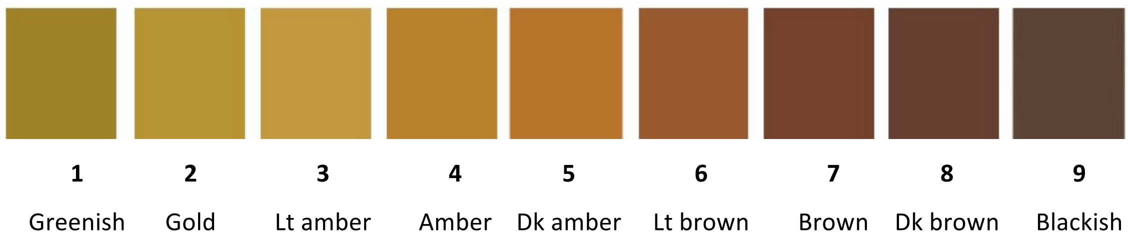


Figure 6- Colour swatches, based on mean colour values for different colours of sultanas.

The base colour description from the industry specifications (Table 3) was compared with the base colour of the sultanas in the colour swatch (Figure 6). Base colour was defined as the dominant colour in the sample, with any base colour of 5 or less (dark amber) considered light, while 6 or more (light brown) was considered brown.

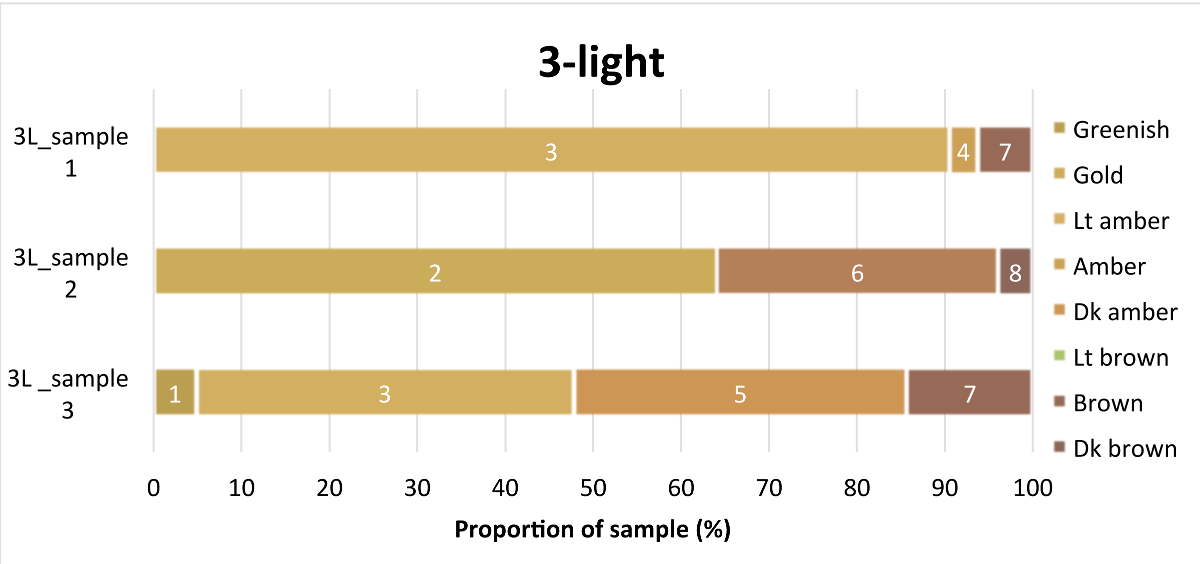
Dark berries were defined as those brown to blackish in colour, corresponding to colour grades 7,8,9 (Figure 6).

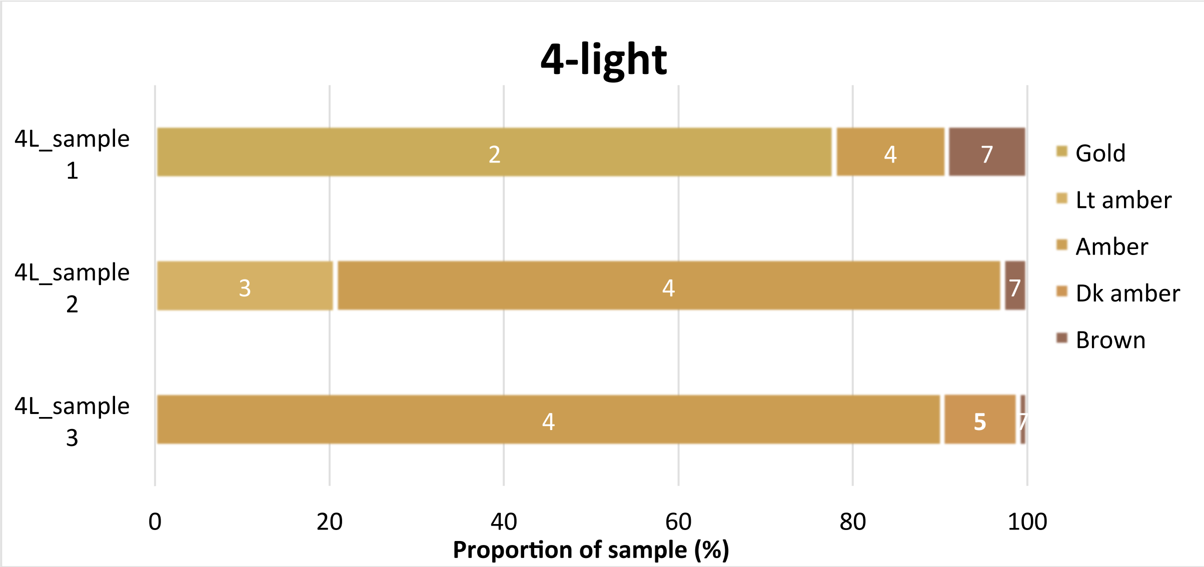
Table 3- Industry sultana grades

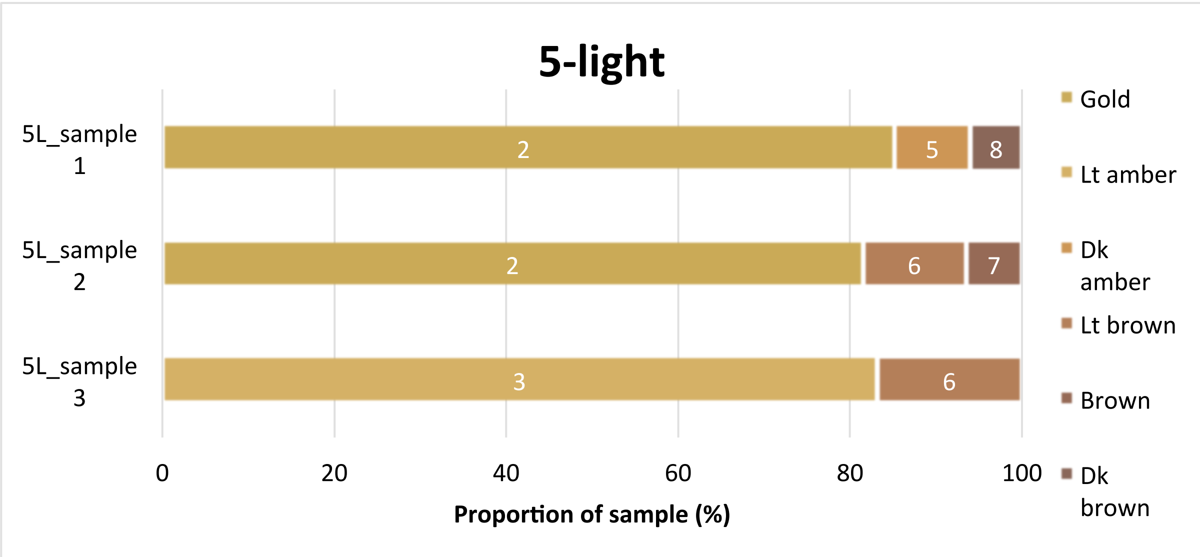
Grade		Base colour of fruit	Colour of remaining fruit
LIGHT	6CL	Bold, bright amber colour	5% dark berries
	5CL	Light amber colour	10% dark berries
	4CL	Average amber colour	15% dark berries
	3CL	Amber to light brown	20% dark berries
	2CL / standard	Light brown	50% dark berries
DARK	5CB	Dark amber colour	10% dark brown berries
	4CB	Dark amber to brown	15% dark brown berries
	3CB	Uniform brown	20% dark brown berries
	2CB / standard	Uniform dark brown	N/A

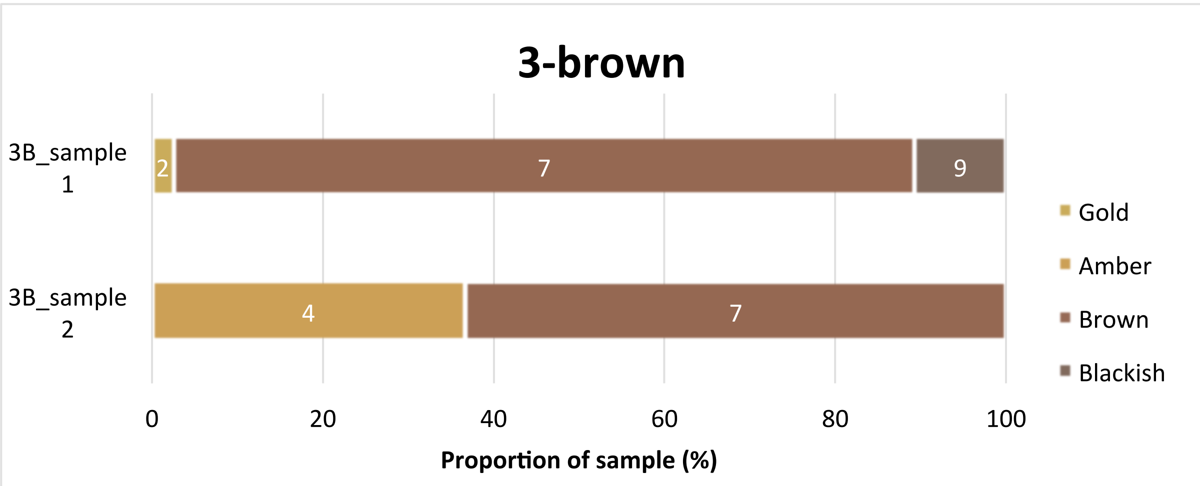
2.3. Results

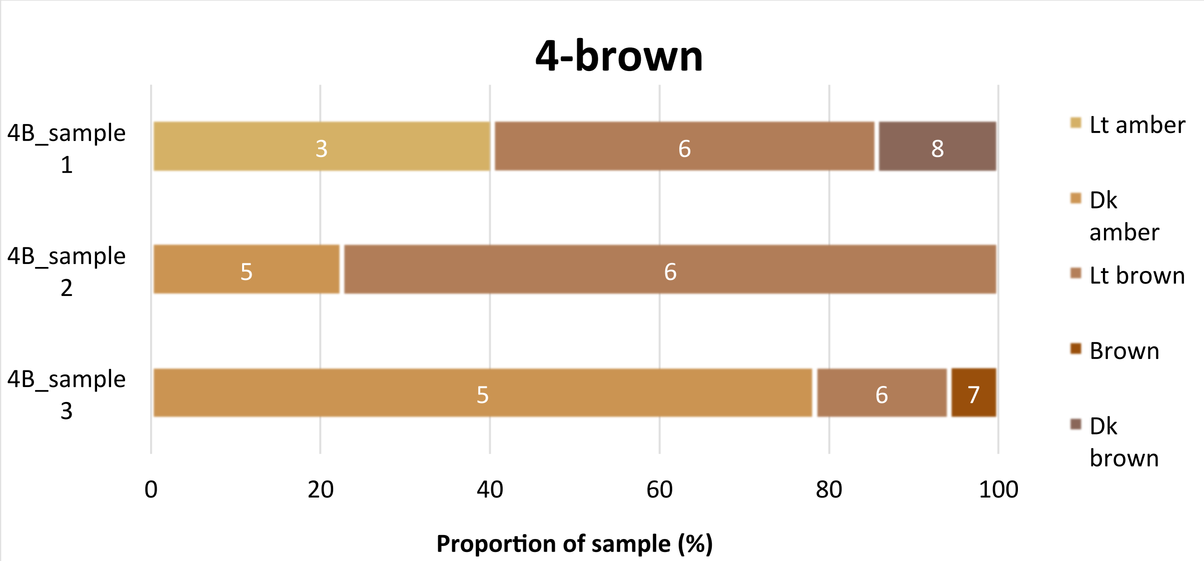
There was considerable variability among the samples, even those assigned the same grade. While only a relatively small number of berries was inspected and colour graded for each sample, it seems apparent that the colour grades assigned do not always match with the descriptions in the grade standard (Table 4).




4-light
4L_sample 1
4L_sample 2
4L_sample 3
2
4
7
3
4
7
4
5
Gold
Lt amber
Amber
Dk amber
Brown
0
20
40
60
80
100
Proportion of sample (%)


5-light
5L_sample 1
5L_sample 2
5L_sample 3
2
5
8
2
6
7
3
6
Gold
Lt amber
Dk amber
Lt brown
Brown
Dk brown
0
20
40
60
80
100
Proportion of sample (%)


3-brown
3B_sample 1
3B_sample 2
2
7
9
4
7
Gold
Amber
Brown
Blackish
0
20
40
60
80
100
Proportion of sample (%)



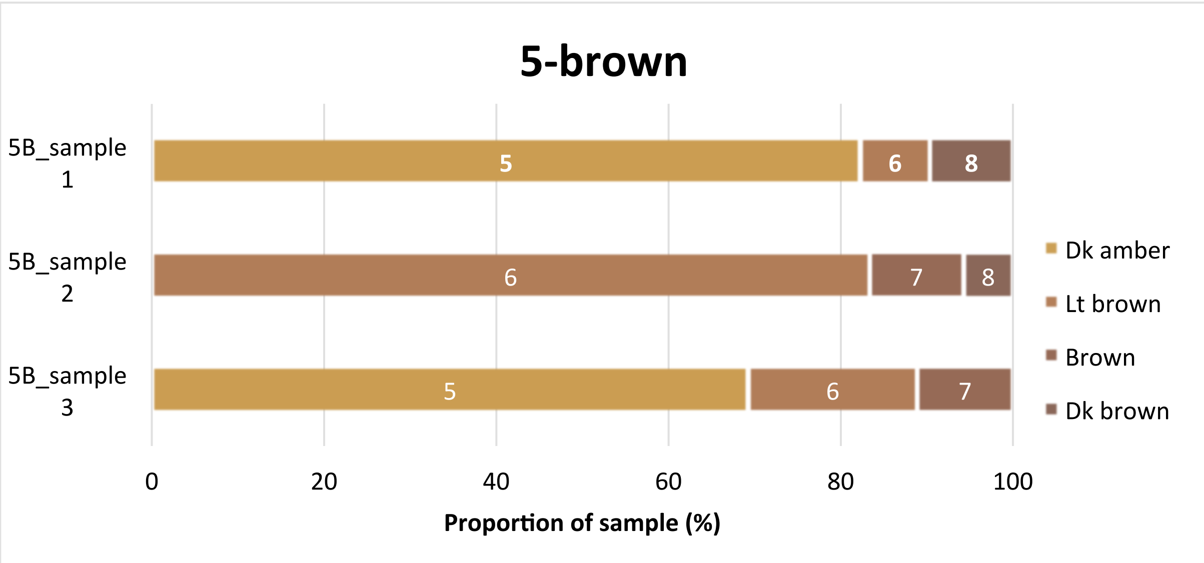


Table 4. Grading of sultanas by processors versus using colour segregated graphs

Sample	Base colour	Dark berries (%)	Processor grade	Alternate grade?
3L-_sample 1	Light amber	6.3	3L	5L
3L_sample 2	⅔ Gold ⅓ Light brown	3.9	3L	3L
3L_sample 3	Light amber	14.3	3L	4L
4L_sample 1	Gold	9.2	4L	4L
4L_sample 2	Amber	2.9	4L	4L
4L_sample 3	Amber	1.1	4L	4L
5L_sample 1	Gold	6	5L	5L
5L_sample 2	Gold	6.5	5L	5L

5L_sample 3	Light amber	0	5L	5L
3B_sample 1	⅓ Amber ⅔ Brown	97.4	3B	3B
3B_sample 2	Brown	63.3	3B	4B
4B_sample 1	Light brown	14.4	4B	4B
4B_sample 2	Light brown	0	4B	4B
4B_sample3	Dark amber	5.9	4B	3L
5B_sample 1	Dark amber	9.6	5B	5B
5B_sample 2	Light brown	5.7	5B	4B
5B_sample 3	Dark amber	11.1	5B	4B

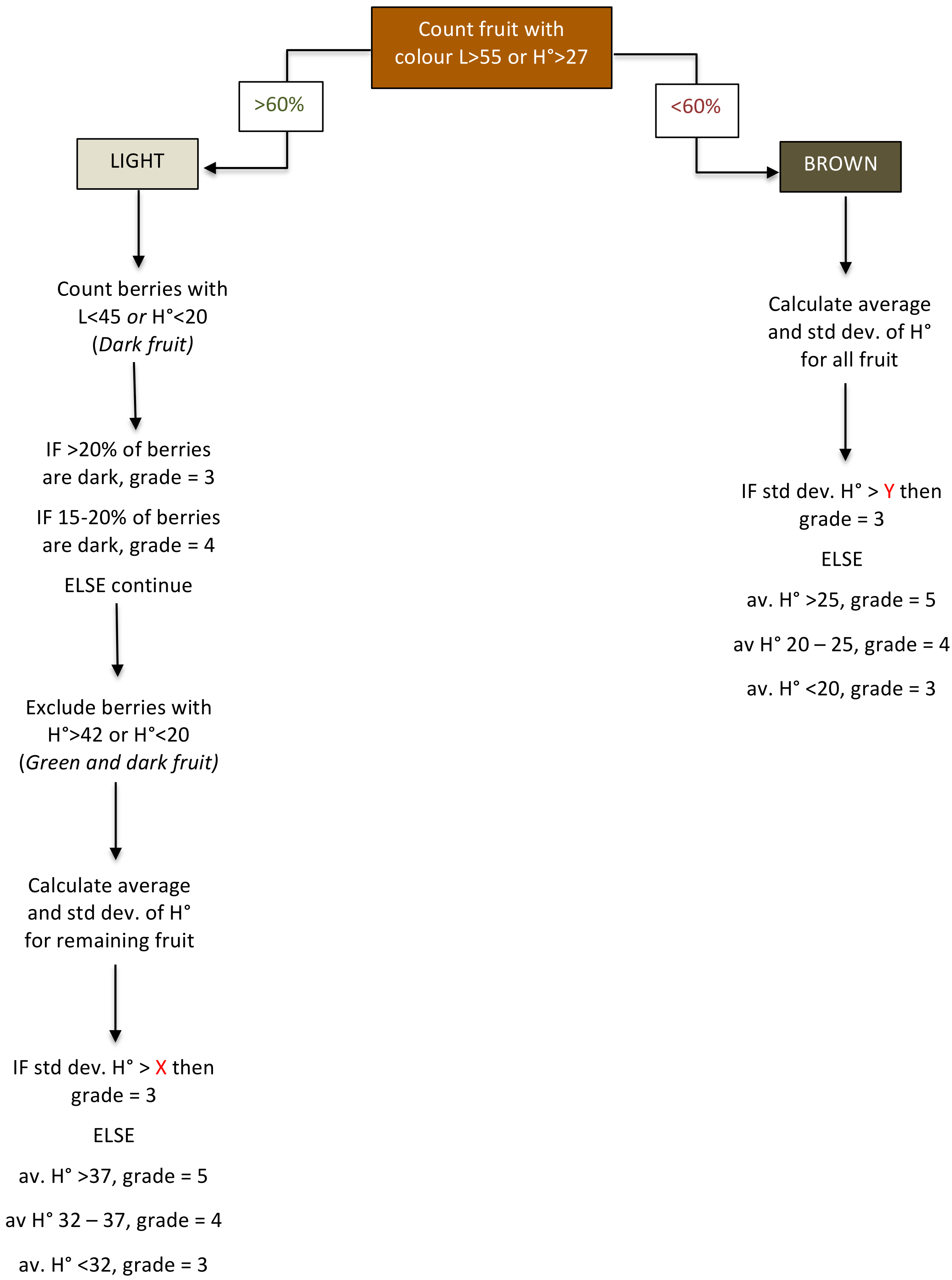
One of the reasons grading is so difficult is that the industry grades define both a base colour, and the percentage dark fruit. If the base colour is light but the percentage of dark berries is high the sample cannot be described using the existing system. Similarly, a darker base colour but with very small number of dark berries also cannot be defined.

This raises the question of what is the key determinant of grade – base colour or dark berries?

As the sultanas are colour sorted as they move through the processing line, it seems likely that the factor which will most determine value is the number of light fruit. That is, fruit which have a score of 5 or less against the colour swatches shown in Figure 6. If the majority of these fruit are Light amber (3) rather than Dark amber (5), then this may add additional value to the batch.

If less than half of the fruit (<60%?) are light coloured, it will not be worthwhile to colour grade the batch. In this case, the variability within the sample may determine value, with more homogenous batches valued more highly.

3. Proposed logic flow for grading system



4. Grading sultanas from a bulk photograph

4.1. Aim

To determine whether a bulk photograph can be used to objectively grade dried fruit consistent with the current system.

4.2. Method

Photographs of trays of sultanas were imported into Photoshop and adjusted using black and white balances. The centres of individual fruit within each tray were selected and averaged using the “blur” tool. The Hue angle and L value of each berry was then recorded using the “colour picker” tool. Approximately 80–90 individual berries per sample were measured in this way.

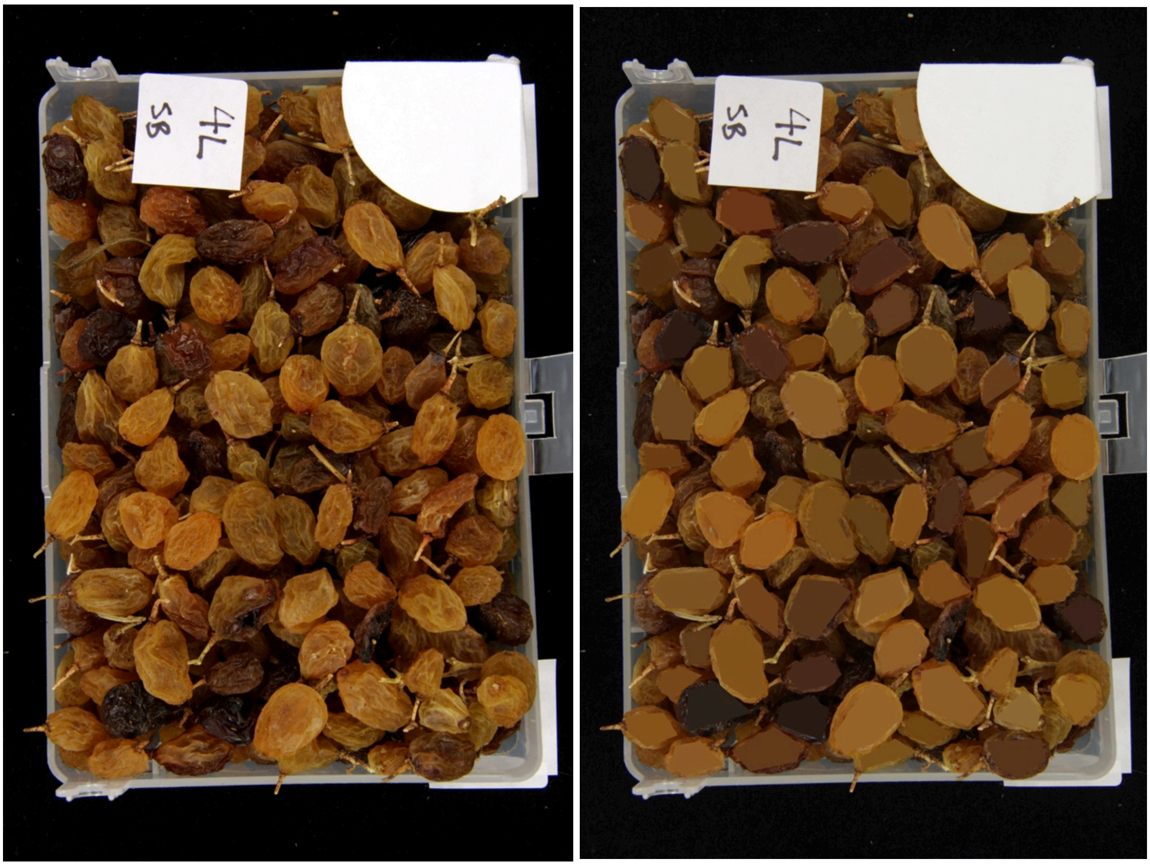


Figure 7 - Example of a photograph of a sample of sultanas, showing the initial photograph and with the colour of individual berries averaged and measured using the Photoshop blur and colour picker tools.

The results were then analysed in terms of:

- the number of dark fruit
- average value of remaining fruit
- variability within the sample

Additional values were recorded for each whole tray of sultanas for:

- the average of the whole tray
- the average of the whole tray with dark areas deleted from the photograph

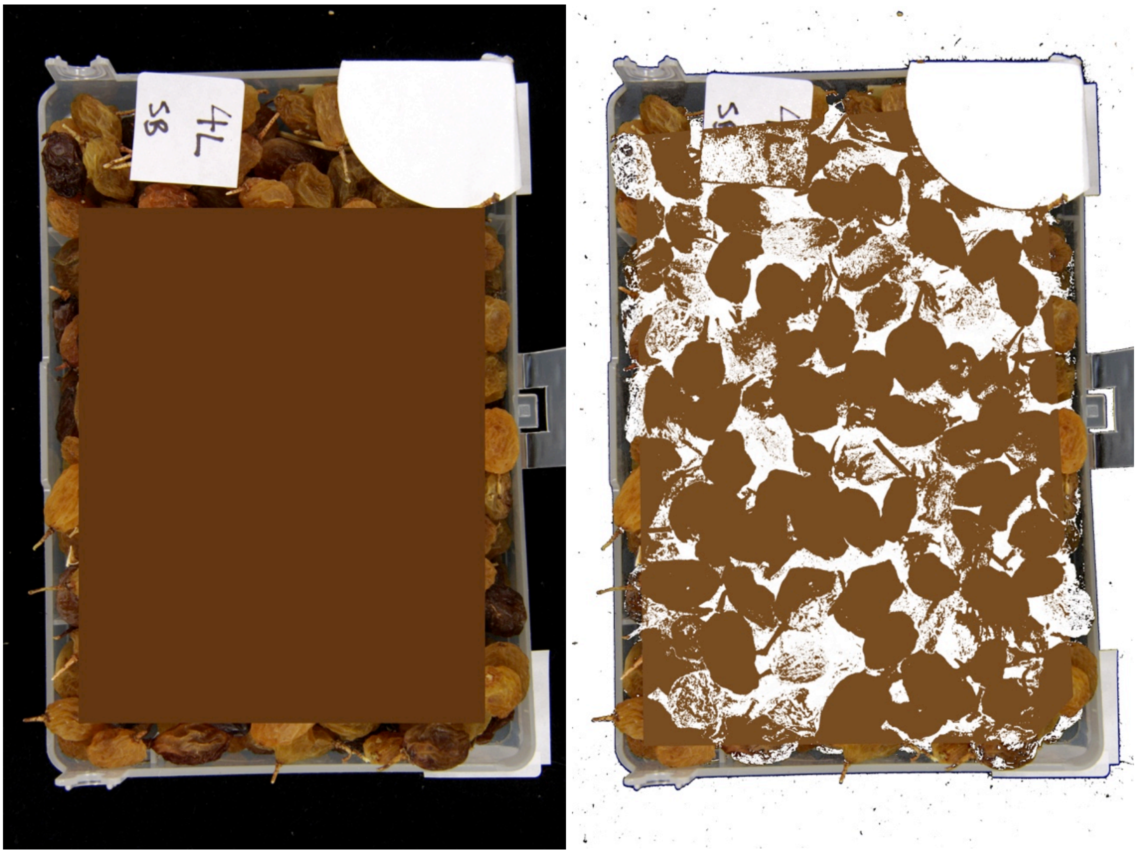


Figure 8 - Example of a photograph of a sample of sultanas, showing the whole tray (left) or only the lighter areas of the image (right) averaged and measured using the Photoshop blur and colour picker tools.

5. Grading sultanas from a scanned image

5.1. Aim

To determine whether a scanned image can be used to objectively grade dried fruit consistent with the current system.

5.2. Method

Images were initially processed to remove noise and eliminate the effects of the wrinkly surface of the dried fruit. A symmetric Gaussian filter was used with a standard deviation of 3. Unwanted parts of the image such as sticks, pedicels and blemishes were removed from the image. The image was then converted into HSV, this being a colour space commonly used by machine vision systems. A mask was generated to separate fruit from each other and the background area. Threshold values were implemented for hue and saturation, separately and in combination. The process used is summarised in Figure 9.

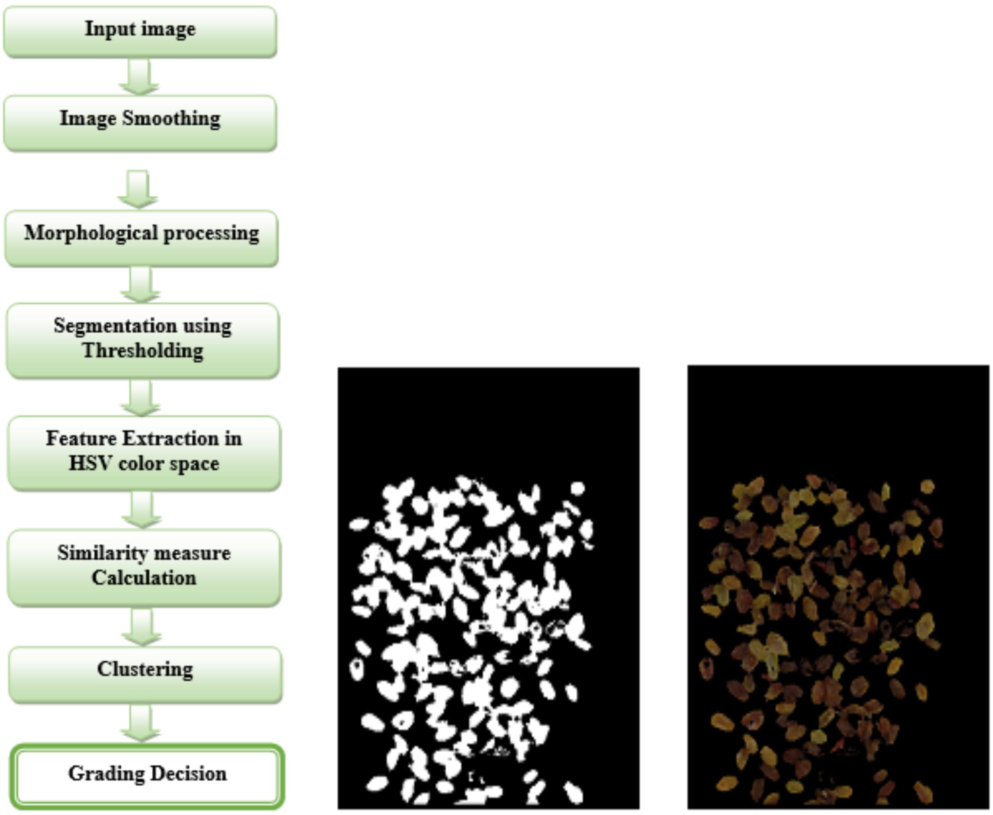


Figure 9. Flow diagram for proposed methodology, and the mask and segmented fruit regions of a scanned image.

5.3. Results

Hue proved a better delimiter for defining differences in colour between batches of sultanas than other values tested. However, the best results were gained when both hue and saturation were used to define colour.

Table 5. Grading of sultana samples with a machine vision system using hue, saturation or hue + saturation as delimiting values. Measured grade was either the same, or different to, the grade allocated subjectively by the processors.

	Saturation only		**Hue only**		**Hue and saturation**	
	Same	*Different*	*Same*	*Different*	*Same*	*Different*
Light	7	11	12	6	12	6
Brown	14	4	5	13	9	9

Raisin Grading Using Machine Vision

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Abstract— **This study attempts to develop machine vision based raisin detection and grading system. An approach based on simple nearest neighbor technique. The HSV color space is chosen to make the system dependent only on the color descriptions and more natural to the human vision. The developed algorithm initially processes the images to remove the noise and then extracts the fruit region by applying thresholding to the hue and saturation channels. Color features for every pixel are extracted and then they are clustered on the basis of their distance from the base colors. A comparison of the results show that the performance is significantly higher when the hue and saturation features are used together as compared to when used separately.**

Keywords—*Raisin grading, clustering, color features, HSV color space, color image segmentation*

I. Introduction

Raisin is an agricultural product of most geographical regions of the world. The Australia is one of the significant raisin producers. Other countries producing raisins include China, Turkey, Iran, Greece, South Africa and Chile. Raisins are produced with variety of grapes using different techniques that result in massive variance among the quality and price of different raisins. One of the important reasons for the low price raisins is their quality and lack of uniformity [1]. This is due to the manual sorting. Manual sorting and grading is expensive and unreliable due to the subjective nature [2]. Human visual classification is time consuming, unpredictable, tiresome and also depends upon the characteristics [3]. The need of the hour is to accurately classify and grade the raisins due to the increased quality and safety standards for food. The use of machine vision and image processing techniques is recommended as it uses the spatial and spectral information. The automatic raisin grading system can improve the raisin quality. Such systems demand lesser manpower and help to eliminate unreliable manual evaluations. Besides, these systems provide real time cost effective, stable, high speed, precise and accurate assessment of the products.

II. Previous Works

The Computer Vision technologies combined with Artificial Intelligence (AI) can be a good alternative for the automatic quality classification and assessment. Computer vision is a valuable tool for the feature analysis like shape, size, stem recognition, color uniformity and color intensity. In the recent era, researchers have applied various machine vision techniques like such as artificial neural network, genetic algorithm, fuzzy logic and statistical learning to refine the product quality examination.

Okamura et al. [4] graded raisins using machine vision. They used visual features of wrinkle edge density, average gradient magnitude, angularity, and elongation. A Bayes classifier was used to grade the raisins into better or B, C and substandard grades. Kicherer et al. [5] proposed a high throughput image processing tool. Berry Analysis Tool (BAT) was used to automatically obtain number, size, and volume of the berries from the RGB images. A black construction was used to place individual berries of one cluster and capture the image. HSV color space images were used to separate the construction and the background. Classification of the berries and background was done using a combination of active learning and logistic regression. Circular Hough Transform was used to detect the round objects (berries). BAT results were very much correlated with the manual evaluations and showed only a little divergence.

Omid et al. [6] proposed a machine vision system and implemented an efficient algorithm for grading the raisins. The algorithm initially extracts the fruit region by removing the background from the images. It uses a combination of color and size features to sort the raisins. The raisins are graded into two classes using suitable RGB color values and length of the raisins. The critical point in this algorithm is to search for the upper and lower pixels for the middle of each column. The center of gravity of each raisin is calculated as a final step of the algorithm that was to be used in the sorting and rejection of defective raisins. The system provided results with 96% accuracy.

Yu et al. [7] presented an approach based on the color and texture features to sort the raisins. Three techniques Linear Discriminant Analysis (LDA), Soft Independent Modelling of Class Analogy (SIMCA) and Least Squares Support Vector Machine (LSSVM) were used for developing different models of classification. Color features and texture features were obtained using two different color spaces: RGB and HSI. This paper basically presented a comparison of the variance in the performance of the combined color and texture features to that of the separate color features and texture features. Color features were obtained using the normalized histograms. The color features used were mean value, variance, skewness, kurtosis, energy, and entropy of the analyzed image histogram. Each color channel was assigned a color feature vector. Finally the color feature vector had 18 features for each of the color spaces. Texture features were extracted using Grey Level Co-occurrence Matrix (GLCM) - a statistical texture analysis technique. The GLCM were normalized and probabilities instead of the counts were represented. Six legendary Haralick features were studied using GLCM. These features were contrast, dissimilarity, homogeneity, angular second momentum, entropy, and correlation. The texture feature vector finally had 18 features just like the color feature vector. The results indicated that the combined color and texture features performed with the high classifying accuracy. Of all the methods best classification result with around 95% accuracy was achieved with LSSVM in HSI color space.

Abbasgholipour et al. [8] an experimental apparatus was designed using machine vision for sorting raisins. Color is the key parameter for classifying and grading the raisins. An efficient algorithm was implemented and tested with aim to use image processing techniques and to obtain features from the captured images. The algorithm basically consists of three steps: remove the background, extract the length and color features and calculating the center of gravity. The color features were obtained in HSI color space. The raisins were sorted on the basis of Hue, Saturation and Intensity features and then were graded using an appropriate combination of color and length. The center of gravity was used for rejecting the undesired raisins. A statistical model was used to determine the precision of the design. Analysis of effects of various parameters on sorting accuracy is done using SAS statistical tool. The factors studied were the impurity and density percentages of the raisins. The final accuracy of the apparatus and algorithm was 93%.

Abbasgholipour et al. [1] conducted a research to sort the raisins using machine vision technology for various lighting conditions. The image segmentation is done based on the color. The permutation-coded Genetic algorithm is used for separating the regions in HSI color space for the desired and undesired raisins. The detection technology was based on the density of the product and the lighting conditions. Two extremes are used for the product density and intensity lighting factors i.e. under weak lighting and high density and under proper light and low-density product. Images obtained under such conditions were mosaicked to check the feasibility of applying the genetic algorithm for detecting the raisins when both the conditions were used in parallel. The GAHSI results were compared with the results of the manually segmented image to evaluate its performance. Its results were same as obtained with the cluster analysis based segmentation.

Mollazade et al. [9] conducted a study to compare different data mining classifiers for grading raisins using visual characteristics. Images of four different classes of raisins were used. First of all the images were pre-processed and then segmentation was done. A total of 44 features were extracted including 36 color features and 8 shape features. Best features were selected using correlation based feature selection. Seven features were found to give better results. Four data mining techniques used consisted of Artificial Neural Network (ANN), Support Vector Machine (SVM), Bayesian Network (BN) and Decision Trees (DTs). These techniques were evaluated using WEKA. Validation results showed that ANN performed best with 96.33% accurate results. After ANN, SVM provided 95.67%, DTs gave 94.67 and BN had 94.33% correctness.

Pawar et al. [10] proposed a cost effective method for grading the bulk of raisins using color texture features extracted using HSI color space. One important specialty is the fuzzy logic classifier used for classification. A total of 21 features were extracted using Spatial Grey-level Distribution Matrix (SGDM). Based on the features a fuzzy classifier was designed that used Gaussian membership function. The system was evaluated by calculating the success rate for different features.

Xiaoling et al. [11] presented a processing method for the raisin grading using neural networks. The researcher determined the length of the long-short-axis and pointed out its location and extracted 7 features such as length, width and chroma. Out of 7, four features were considered the key parameter of the BP input of the network to make a network to identify the level of the raisins by analysis of its external characteristics. Their method used the classic feature detection and boundary tracking algorithm.

III. Materials and Methods

The main objective of this paper is to develop an efficient algorithm following the ‘keep it simple and stupid (KISS) principle for grading the raisins by evaluating the color features and the variability of color in each batch and to compare the manual grading system with the visual grading system.

A. Experimental Setup

Raisins samples were collected in Mildura that were already assigned the color grades. A sub-sample of 50g was taken from each of the 3 samples from six different color grades. Samples were assessed in a light up box set up as shown in Fig. 1. With a Crompton natural daylight (6500K) fluorescent light.

Fig. 1. Light box setup for assessing color of raisins

Raisins were separated into the base colors and the proportions of other colors. Color of the berries was determined using a color scale shown in Fig. 2. The base colors were obtained based on the mean value for different colors of raisins. Base colour was defined as the dominant colour in the sample, with any base colour of 5 or less (dark amber) considered light, while 6 or more (light brown) was considered brown. Dark berries were defined as those brown to blackish in colour, corresponding to colour grades 7, 8, 9.

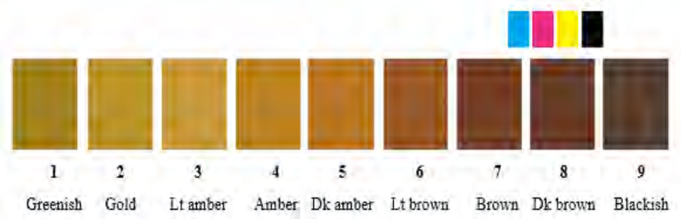

Fig. 2. Base color Swatches used in grading

One of the reasons grading is so difficult is that the industry grades define both a base colour, and the percentage dark fruit. If the base colour is light but the percentage of dark berries is high the sample cannot be described using the existing system. Similarly, a darker base colour but with very small number of dark berries also cannot be defined.

Base color	Variability (crown)
Light	6
	5
	4
	3
Brown	5
	4
	3

Table 1. Raisin Grades in current grading using the color and variability

Using the above setup images were captured. In the dataset being used, there are total 36 scanned images of three types of samplesof raisin. The images are obtained with two different background colors i.e. white and black.

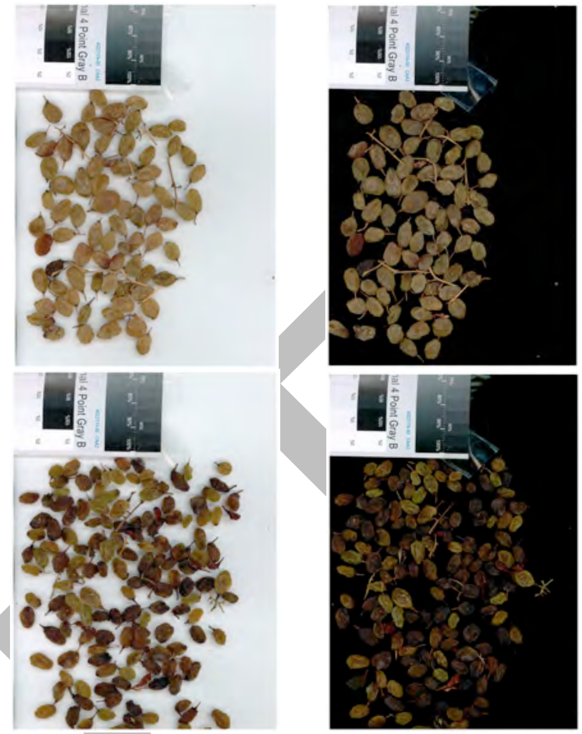

Fig. 3. Random Sample Images from dataset

Grade		Base color of fruit	Color of remaining fruit
LIGHT	6CL	Bold, bright amber color	5% dark berries
	5CL	Light amber color	10% dark berries
	4CL	Average amber color	15% dark berries
	3CL	Amber to light brown	20% dark berries
	2CL / standard	Light brown	50% dark berries
DARK	5CB	Dark amber color	10% dark brown berries
	4CB	Dark amber to brown	15% dark brown berries
	3CB	Uniform brown	20% dark brown berries
	2CB / standard	Uniform dark brown	N/A

Table 2. Industry Standard grades for raisin grading

B. Methodology

We present a method to color grade the raisins using the color features in HSV color space in combination with the nearest neighbor technique. Our proposed method simply consists of preprocessing the image, fruit region extraction, feature extraction, clustering and finally assigning the grades.

First of all, the input is taken as the image. The images are naturally noisy due to different types of errors. In our case even the color and illumination of a single raisin varies due to the wrinkles in the surface. To cope with the effects of the wrinkles and to remove noise, a symmetric Gaussian filter of the size of the input image is applied to the image. The smoothness of the output of the filtered image depends upon the standard deviation. Higher the standard deviation, the greater the smoothing is. We experimented with a range of values of Sigma and the results with the appropriate level of detail are obtained using a value of 3.

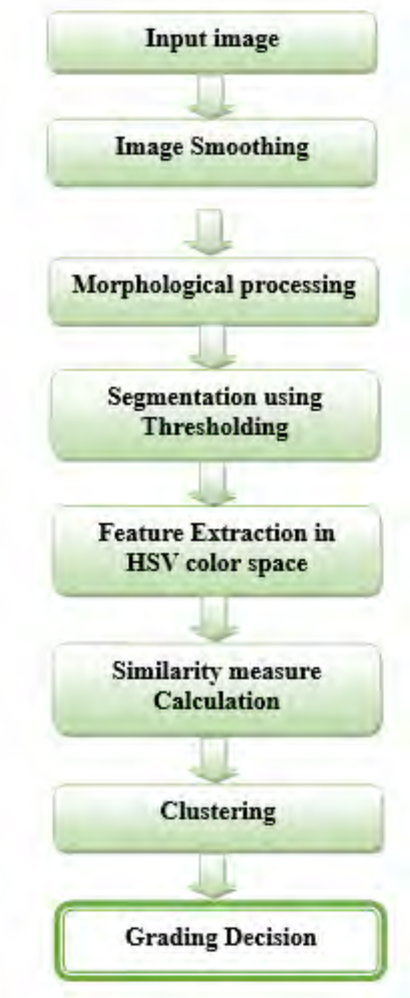

Fig. 4. Flow diagram for the proposed methodology

After image smoothing, some morphological operations are performed to remove the unwanted pixels and blemishes (the raisin branches) from the image. The structuring element used in the morphological operations is disk and the size giving better results is 7. With this size of disk all the noisy elements are removed without damaging our fruit region. First of all the image is dilated and then reconstructed after eroding the dilated image. Morphological reconstruction in combination with opening with a closing removes the dark spots and removes the gaps between the objects that are connected by the thin bridges. Reconstruction based on opening and closing are more effective than simple opening and closing in removing all the undesired elements from the image without effecting the original shape of the raisins. Opening is an erosion followed by dilation. We instead of using standard opening and closing, used erosion followed by dilation twice that removes all the unwanted spots and stems.

After all the preprocessing steps, the image is converted to HSV image and we obtain a mask using the Otsu's Method. The threshold is applied on the Hue and Saturation channels separately. Otsu's thresholding is global thresholding method. It computes a threshold level and converts the image to binary image. At first two separate masks using Hue and Saturation components are obtained then both are combined using the logical operators. Then that mask is multiplied with the original image to get the fruit region. A sample mask and segmented image are shown.

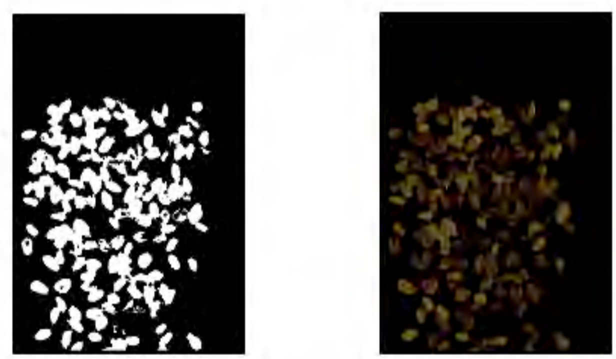

Fig. 5. Mask and Segmented Fruit Region

The representation of colors in the RGB color space is designed for the specific devices and covers only a range of colors. We choose HSV color space to make our algorithm dependent on the color description that are natural to the human vision instead of making it device dependent. The advantage of using HSV is that hue is invariant to the shading and highlights [13].

A variety of features can be extracted. A detailed study of types of features that can be obtained and sensors and systems is present in [12]. The result of the segmentation was the image containing the fruit region with the black background shown in Fig. 5. For each pixel we extract hue and saturation values. We experimented first using the hue and saturation features separately and then combined them to form a 2D feature vector. The 9 base colors are used as fixed centroids and the distance of each pixel from all the centroids is calculated then the pixel is assigned to the cluster with which it is having the minimum distance. The similarity measure used is squared Euclidean distance. In the end the raisins are graded according to the proportion of each color sample. The grades are assigned on the basis of the percentage of the dark berries given in Table 2.

IV. Results And Discussion

The algorithm implemented was tested on all the 36 images of dataset first using the Hue and Saturation separately and then experimented using the combined feature vector. The accuracy of the results is depicted in form of confusion matrix. The best results are obtained using the both hue and saturation at a time as features with accuracy 77%. After that, the hue feature when used separately performed with 66% while the saturation feature performed poorly with only 38% correct results.

Original grade	Correctly classified	Incorrectly Classified
Light (18)	7	11
Brown (18)	14	4

Table 3a. Results using Saturation as the only feature

Original grade	Correctly classified	Incorrectly classified
Light (18)	12	6
Brown (18)	9	9

Table 3b. Results using Hue as the only feature

Original grade	Correctly classified	Incorrectly classified
Light (18)	12	6
Brown (18)	5	13

Table 3c. Results using H & S as features

V. Conclusion

An efficient and simple method was adopted to grade the raisins. By choosing a proper color space and suitable and informative features we can precisely grade the raisins without being affected by the problems like lighting and shading effects. It is not necessary that using more features always increase the accuracy. The key point is to use the relative and more informative features related to the problem at hand. By using this machine vision system we can tackle the problems that we face in the manual grading and can eradicate the inconsistencies.

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