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Potential Performance Criteria for Combat Ration Packs - Colour

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ABSTRACT

The Australian Department of Defence standard specifications for combat ration pack (CRP) food components include functional and performance criteria to ensure that components procured are suitable for their intended purpose. Sensory analysis of appearance does not provide an objective basis for decisions to be made on product colour acceptability. The human perception of colour is subjective and varies among individuals, whereas instrumental methods provide objective data. Instrumental colour analysis information collected during storage trials has been reviewed and considered as an alternative for developing performance criteria for CRP components. There were significant changes in the colour values of some CRP components during the two year storage period. Correlation of this data with the results of sensory evaluations could support the development of CRP performance criteria based on colour.

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Executive Summary

The Australian Department of Defence standard, DEF(AUST), specifications for combat ration pack (CRP) food components include functional and performance criteria to ensure components procured are suitable for their intended purpose. However, DEF(AUST) specifications do not currently include criteria for measured colour. There is potential to include CIE (International Commission on Illumination) L*a*b* colour analysis performance criteria.

The purpose of this report is to review colour measurement data for its usefulness in establishing performance criteria for CRP food components.

Conclusions:

- The L*a*b* TCD value can be used to establish performance criteria for certain CRP components
- Further research is required to establish TCD performance criteria
- Baseline acceptance criteria are needed to support the use of TCD performance criteria
- Colour charts could be established (using sensory panellists) to reflect a more objective score for component colour acceptability.

Recommendations:

We recommend that CASG adopt CIE L*a*b* TCD values as a measure to ensure colour changes of CRP components remain within acceptable limits.

Implementation of this recommendation should be based on further research to:

- establish baseline L*a*b* values and colour tolerance ranges for new and existing CRP components
- adopt the CIE L*a*b* TCD value as a measure to ensure colour change of CRP components remains within acceptable limits during the warranty period
- develop visual colour assessment charts to establish colour tolerances for use during sensory analysis for components that exhibit large colour changes
- investigate correlation of perceived sensory colour change with instrumentally measured colour data for light coloured components.

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Contents

Glossary

a*	red/green colour-opponent dimension
b*	yellow/blue colour-opponent dimension
C	chroma
CASG	Capability Acquisition and Sustainment Group
CIE	International Commission on Illumination
CRP	combat ration pack
DEF(AUST)	Australian Defence Standard
DST Group	Defence Science and Technology Group
H	hue angle
L*	luminance
QAP	quality assurance program
SCM	sweetened condensed milk
TCD	total colour difference

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1. Introduction

1.1 Colour as a Sensory Attribute

The under-consumption of combat rations by soldiers is well known. Forbes-Ewan (2009) states that it appears to be a near-universal finding that troops under-eat on operations when rationing is by combat ration pack (CRP). To encourage consumption, it is necessary to ensure that the food provided is visually appealing. Appearance of food is regarded as a central quality, which contributes to the experience of eating. Colour is the visual property most commonly used to determine sensory quality. Colour may also be an indicator for quality of the internal constituents, as texture and flavour can share a relationship with colour (Jha, 2010).

1.2 Colour Change in Food

The colour of a CRP component in theory, is best (or most true) at the time of manufacture. However, there is often a considerable period of time between the point of manufacture and time of consumption. The colour of food can change during processing and storage as a result of physical and environmental, as well as chemical and microbiological, influences. As an example, some foods may appear brown due to the presence of melanoidins. Melanoidins are brown, nitrogen-containing, high molecular weight pigments, responsible for the characteristic colour of roasted foods such as coffee, cocoa, bread and malt. To observe these changes, CRP components are subjected to storage trials, both accelerated and real time. Clydesdale (1991) states that colour affects consumer judgement of other sensory characteristics, such as flavour, sweetness and saltiness.

For many products, such as baked foods, coffee and biscuits, the development of a brown colour during processing is a desirable trait. However, browning during storage is undesirable for some CRP components, e.g. white hazelnut spread and sweetened condensed milk. These components became visibly darker in colour as indicated by their decreasing L* values (refer Section 1.5 for explanation of L*). However, during sensory evaluation these components are often rated 'acceptable' by panellists, regardless of any increase in darkness. Non-enzymatic browning, such as Maillard and caramelisation, is mainly associated with carbohydrate degradation, and causes general darkening of the CRP components during storage.

It has been shown that a relationship exists between colour and water activity (aW), with increases in aW observed in association with both undesirable Maillard browning reactions and colour losses in chlorophyll, carotenoids, anthocyanins and flavonoids (Steele, 2004).

1.3 Limitation of Sensory Analysis for Determining Acceptability of Food Based on Colour

Information on the visual acceptability of food can be gathered through sensory evaluation panels, using questions focused on appearance, with colour being one parameter that is evaluated. However, colour perception is difficult to standardise from data generated during sensory evaluations as individuals see and perceive colour differently. To reduce differences, measurements must be conducted under controlled conditions. Variables including spectral quality, light intensity, size of the light source, the direction the light strikes the sample, the direction the sample is viewed and the distance from sample all must be controlled (Good, 2014). There is also a psychological aspect to how the appearance of food is perceived, with individuals showing biases to particular foods. Perception of colour can change when multiple evaluations are performed. Lawless & Heymann (1998) highlighted that instrumental measurements should be used for evaluations that are repetitive, fatiguing or dangerous.

1.4 Instrumental Measurement of Colour

Instrumental colour measurement can be used to overcome the limitations of sensory evaluation, and can be used to make an impartial decision on the acceptability of food.

It is important for the food industry to have a robust means to measure colour change during processing and storage. Instrumental colour measurement can be used to monitor consistency of products, colour changes and quality during storage. Furthermore, changes in colour can be used to monitor consistency and quality of ingredients during product development and manufacturing (Good, 2003).

1.5 The L*a*b* Colour Model

The L*a*b* colour model was created to serve as an instrument/device independent model (Plenty, 2007), that attempts to linearise the perceptibility of colour differences and mimic the logarithmic response of the eye. L*a*b* colour opponent space (Figure 1) has three dimensions:

- L* - the luminance
- a* - the red/green colour-opponent dimension
- b* - the yellow/blue colour-opponent dimension.

L*a*b* values are integrated into the formula used to highlight overall change of colour in a food. The total colour difference (TCD) provides the useful single number often desired by industry for establishing acceptability limits for a particular food (Neilson, 2006). This value may be useful when setting criteria for certain CRP components, in particular where individual L*a*b* values are not independent of each other. In these cases the use of L*, a* or b* values alone may not convey sufficient information for the setting of performance criteria.

*Figure1 L*a*b* colour-opponent space*

1.6 Combining Instrumental Measurements with Sensory Data

In both industrial and research applications, the interest is primarily how colour dimensions deviate from a standard, or how they change from batch to batch, year to year, or during processing and storage.

Researchers have proposed product-specific colour indices, which allow for direct correlation with a specific food (Pathare, et al., 2013). Quality index colour measurements of certain ingredients and processed foods can be established to provide quality control for measuring conformity of food quality to specifications (Good, 2014). This includes tolerances to monitor the limits within which a product or ingredient is considered acceptable and within quality specifications.

The aim of this work was to provide guidance on how colour could be used in the setting of performance criteria within individual CRP product specifications.

2. Materials and Methods

2.1 Storage Condition

Samples of CRP components were placed on storage as shown in Appendix A, Table A1. These profiles provide real time and accelerated shelf life testing data for a broad range of quality measures. They were not set up solely for detecting and monitoring changes in colour properties.

2.2 Data Collection

Our evaluation was based on in-house instrumental colour data for in-service CRP components from 2008/09, 2009/10 and 2010/11 quality assurance programs (QAPs). Data was available for the components listed in Appendix A, Table A2.

Three to five samples of each component were analysed at each storage profile. Analysis was based on the mean of three readings per sample.

2.3 Instrumentation

HunterLab ColourQuest XE spectrophotometer with EasyMatch Software was used to measure the L*a*b* colour values.

2.4 Calculation and Equations

2.4.1 Change of L*a*b* colour in CRP Components

All calculations used to evaluate colour change of CRP components are presented in Appendix B. These calculations include ΔL^*, Δa^*, Δb^*, Hue Angle (H) and Chroma (C). The TCD equation (below) is the CIE76 equation. It has been used here for simplicity in calculating and demonstrating the potential use of instrumental colour measurements[1].

$$\Delta \boldsymbol{E}^*_{\boldsymbol{ab}} = \sqrt{\Delta \boldsymbol{L}^{*2} + \Delta \boldsymbol{a}^{*2} + \Delta \boldsymbol{b}^{*2}}$$

2.4.2 Rating Scale for Magnitude of the Colour Change

A rating scale was developed to characterise the magnitude of change for each of the CRP components within the 2008/09, 2009/10 and 2010/11 QAPs. Components were rated into the three categories: small, medium and large change and assigned a colour as shown in Table 1.

Table 1 Categories used to classify colour change in CRP components

Small	Medium	Large
0.00 – 4.99	5.00 – 9.99	> 10.00

[1] In the event work is to be done in the future establishing correlations with sensory ratings of colour acceptability then it would be more appropriate to use one of the formulas that corrects for the non-uniformity of the human eye to different colours (e.g. the CIE94 or CIEDE2000 formulas).

3. Results and Discussion

3.1 CRP Components with Attribute/s Displaying a Large Change in Colour

In this investigation, colour change was determined by comparing CRP components that were placed on storage at 1 ºC for 2 years (control or 'initial', storage profile 1) with samples stored at 30 ºC for 2 years (storage profile 18). Table 2 summarises data for the components displaying the largest TCD (>10.00) after two years storage at 30 °C. Components include apricot fruit grains, cheddar cheese, chilli sauce, chocolate spread, fruit pudding, golden pudding (sauce), savoury soup, sweetened condensed milk and tropical fruit grains were found to display the largest TCD.

Figures 2-4 show the TCD for all analysed CRP components from the 2008/09, 2009/10 and 2010/11 QAPs, respectively. Background shading of graphs (as defined in Table 1) has been applied to aid in visualising the relative magnitude of change.

Statistical analysis of L*a*b* data for all CRP components from the 2008-09, 2009-10 and 2010-11 QAPs is presented in Appendix C. Where data for profile 1 was unavailable for comparison, profile 5 was used as the control.

Table 2   CRP components displaying medium to high total colour difference (ΔE)

CRP Component	L* a* b*	L*a*b* Mean (2yrs/30°C)	±SD	Sig (P value)	Δ L*a*b*	Δ C	Δ H	Δ E (TCD)
Apricot fruit grain	L*	40.18	0.45	0.001	-6.97	-15.33	0.587	16.89
	a*	0.70	0.10	0.000	-10.63			
	b*	0.32	0.10	0.000	-11.11			
Cheddar cheese	L*	76.55	0.54	0.000	-9.70	2.48	0.088	11.15
	a*	7.50	0.16	0.000	5.32			
	b*	23.96	0.39	0.017	1.44			
Chilli sauce	L*	28.54	0.28	0.000	-4.34	-9.78	-0.081	10.70
	a*	3.83	0.33	0.000	-8.05			
	b*	3.05	0.48	0.000	-5.56			
Chocolate spread	L*	45.29	1.81	0.002	12.03	-11.37	0.315	16.78
	a*	7.67	0.88	0.039	-4.65			
	b*	8.24	1.25	0.095	-10.74			
Fruit pudding (inside cake)	L*	40.58	0.46	0.003	7.79	-19.33	0.612	21.32
	a*	4.47	0.78	0.000	-6.61			
	b*	4.23	1.19	0.000	-18.72			
Golden pudding (sauce)	L*	57.96	1.95	0.000	26.39	14.35	-0.163	30.12
	a*	11.62	0.62	0.001	4.94			
	b*	24.01	1.64	0.000	13.65			
Savoury soup (10/11)	L*	59.49	1.35	0.000	-10.49	-2.22	0.005	10.72
	a*	5.22	0.15	0.000	-0.82			
	b*	12.05	0.48	0.000	-2.07			
Sweetened condensed milk	L*	55.66	0.39	0.000	-16.51	8.02	0.111	19.72
	a*	8.69	0.09	0.000	8.51			
	b*	26.02	0.17	0.000	6.61			
Tropical fruit grains	L*	38.73	0.40	0.000	-8.42	-15.22	0.505	17.44
	a*	0.98	0.12	0.000	-8.76			
	b*	0.79	0.12	0.000	-12.51			

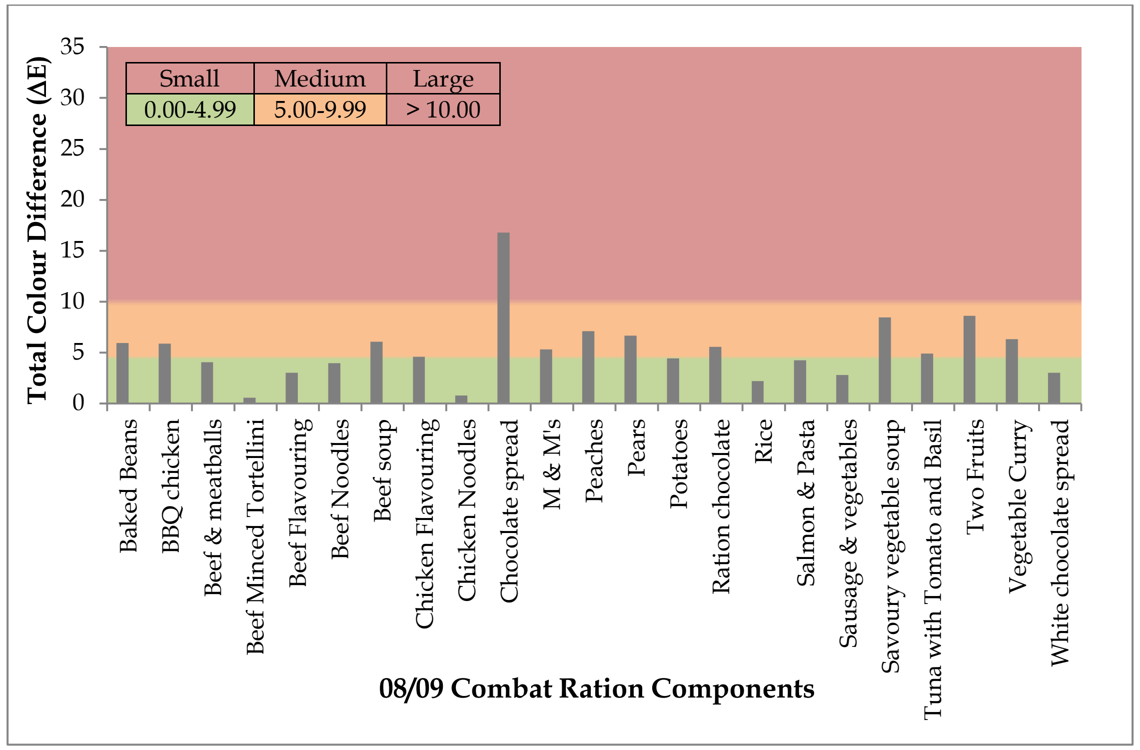

Figure 2 Total Colour Difference values of 2008/09 CRP components stored at 30°C for 2 years

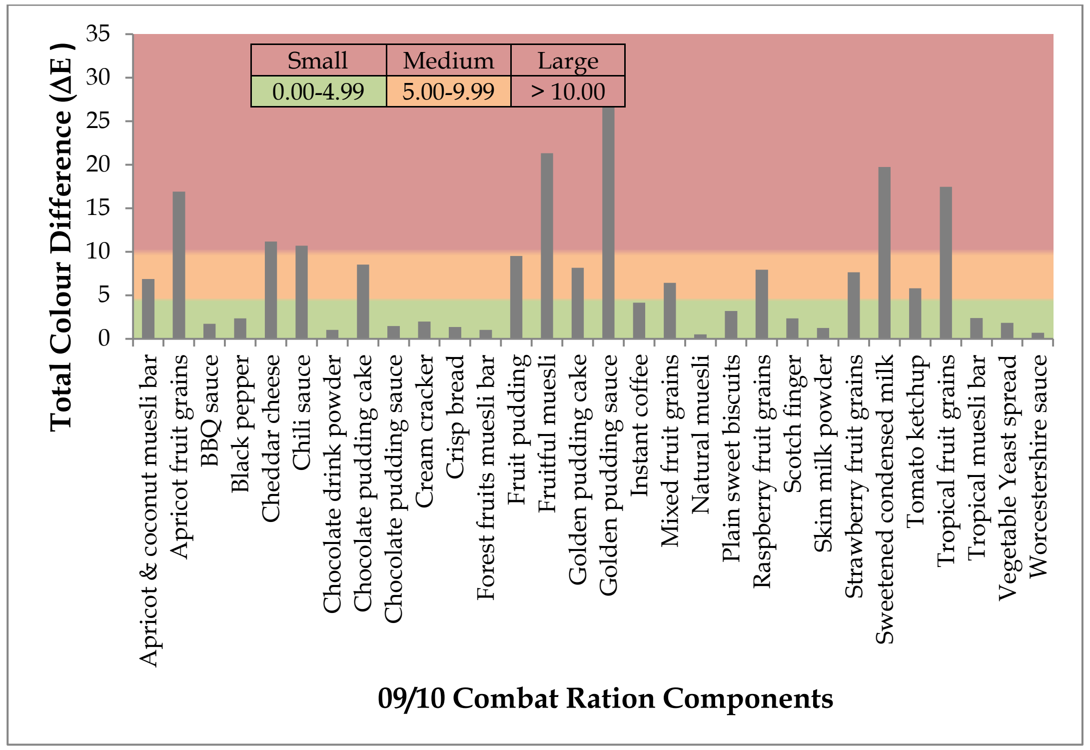

Figure 3 Total Colour Difference values of 2009/10 CRP components stored at 30°C for 2 years

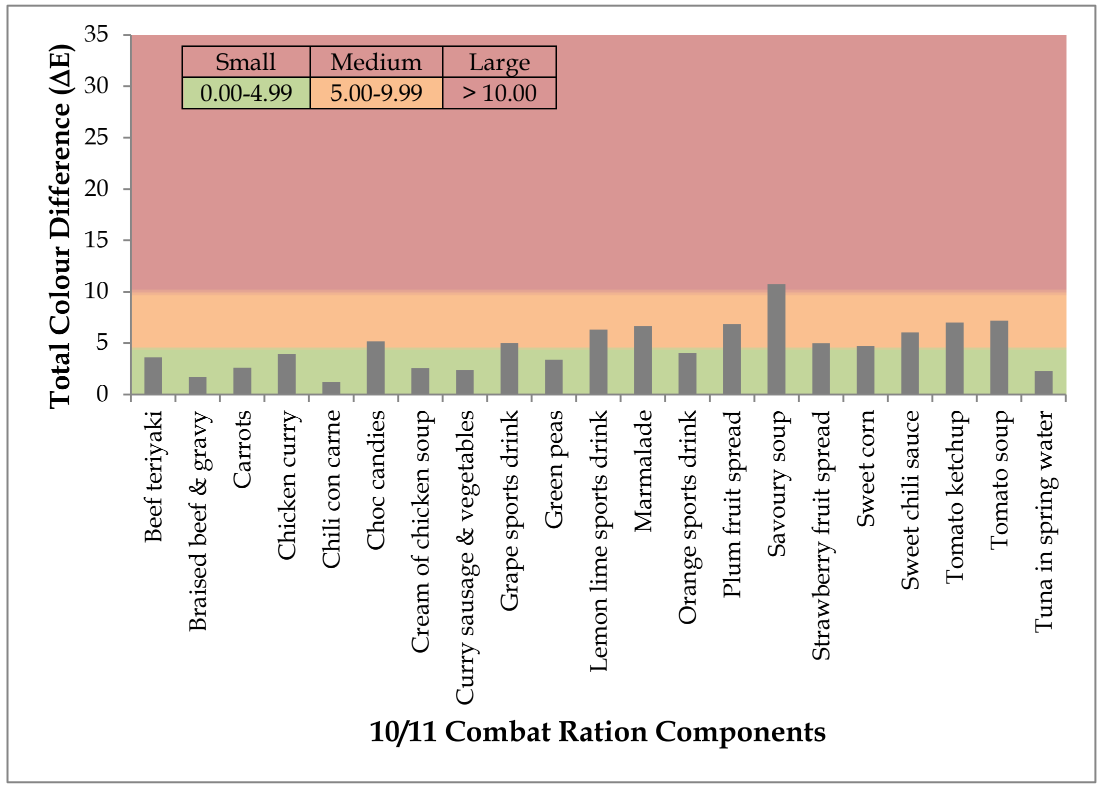

Figure 4 Total Colour Difference values of 2010/11 CRP components stored at 30°C for 2 years

3.1.1 Predicting Colour Change

Graphs (Figures 5 and 6) were constructed, capturing data from each storage profile for selected CRP components listed in Table 2 that had 'large' TCD ratings. The areas shaded in grey represent the region of low or moderate colour change; while the area outside of the greyed area indicates that the colour change has moved into the high category.

The reaction rates of several of the CRP components for which large colour changes were observed appear to be temperature dependant. For example, tropical fruit grains stored at 50 °C for 12 weeks had similar colour values (b*) to products stored for 2 years at 30 °C (Figure 5). Similarly, sweetened condensed milk (Figure 6) followed a predictable pattern, however the 50 °C storage time point at which the L* value was equal to the 2 year at 30 °C value, occurred after approximately 50 days of storage. These components may be suitable candidates for predictive modelling.

Products such as these may not be required to undergo long term storage to determine colour change. The colour change for these components was greatly dependent on storage temperature, with a dramatic decrease observed in the L* value at the higher storage temperatures. This could be a result of a complex array of melanoidins produced by the Maillard reaction and is strongly dependent on the food matrix composition as well as the technological conditions of the reaction (Wang et al., 2011). Melanoidin can also be formed by sugar caramelisation without the participation of amino groups.

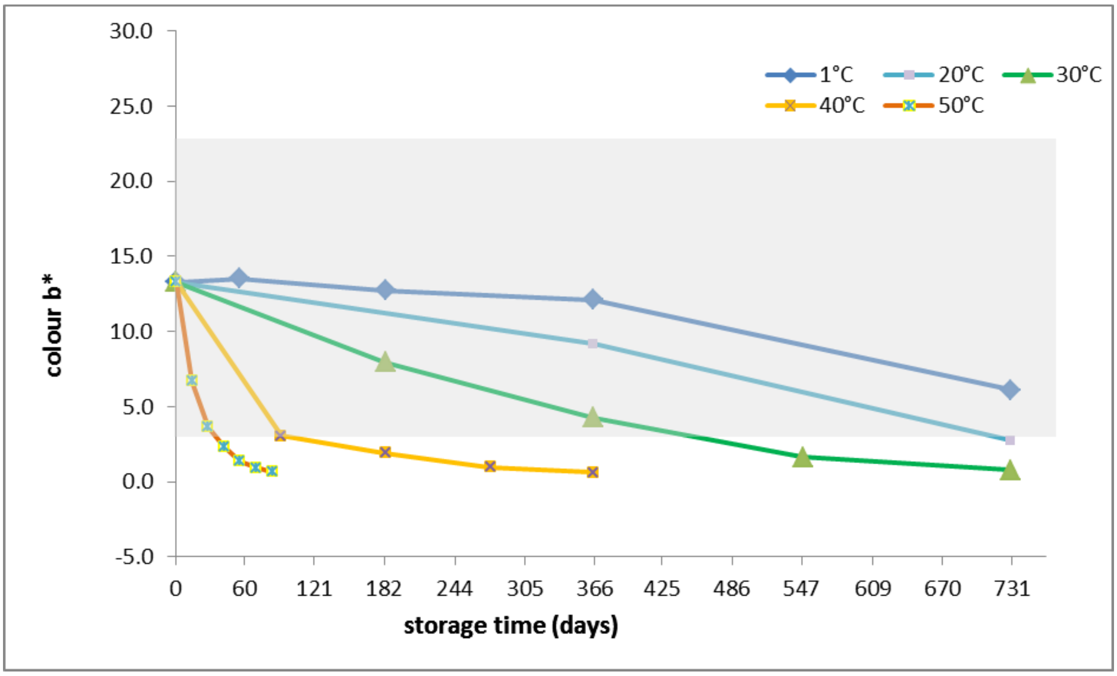

Figure 5 Tropical fruit grains – b colour change during storage*

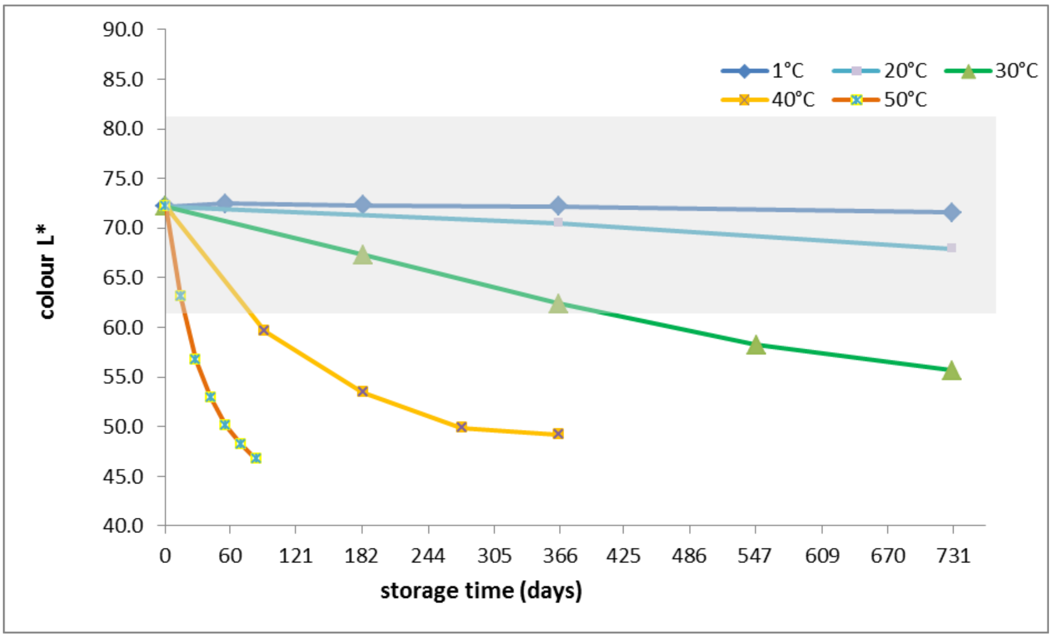

Figure 6 Sweetened Condensed Milk- L colour change during storage*

3.1.2 Location of CRP Components within CEI L*a*b* Colour Space

Figure 7 shows the location of colour within the 3 dimensional L* a* b* colour space. The majority of CRP components were located in the highlighted region, with respect to the L* a* b* coordinates.

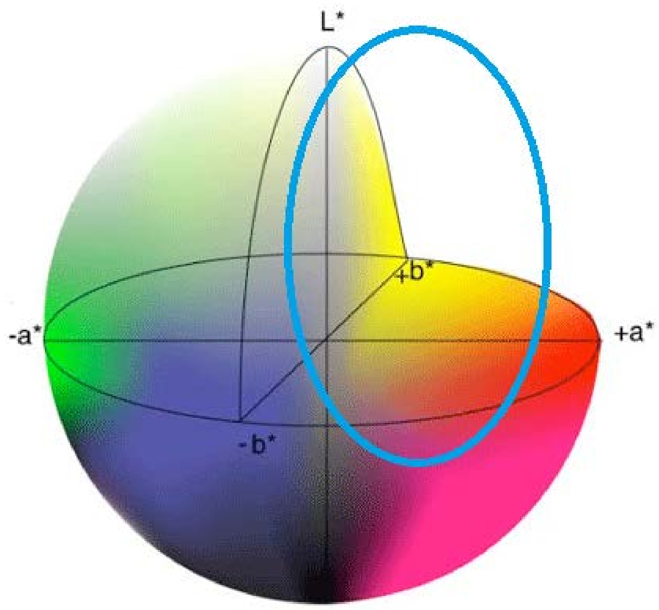

Figure 7 Location of the majority of CRP components within L a* b* colour space*

Components that are pale yellow or white, such as rice, chicken soup and noodles, are located high on the L* axis, while darker products such as baked beans and tropical muesli bars were low on this axis.

Colour data for all CRP components in all QAP is presented in Appendix C, Table C1-C3. Calculations of ΔC, ΔH and ΔTCD are also included in these tables. The magnitudes of the colour changes are categorised as detailed in 2.4.2.

3.1.3 Establishing Colour Charts

Colour charts have been developed for the food industry, for evaluating colour acceptability of foods including fruit, potato chips, salmon and beef. Figure 8 is an example of a chart that has been developed for the sensory evaluation of potato chips (Pedreschi et al., 2011).

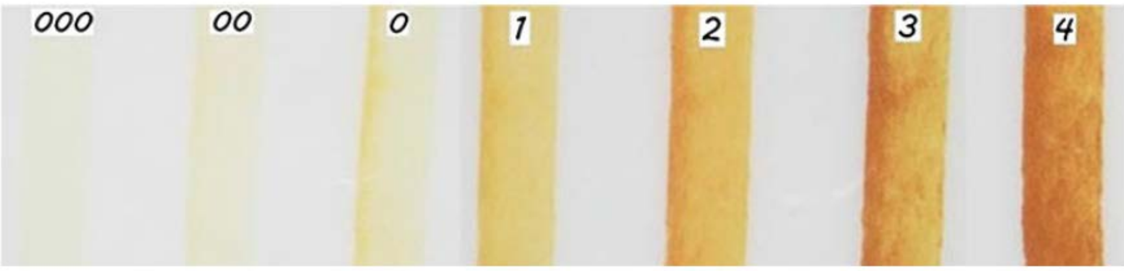

Figure 8 Example of a colour chart (potato chips) of the type that could be used to verify component acceptability

These quality categories were established according to surface colour using 79 frequent consumers of potato chips. Table 3 summarises the grades used in the establishment of quality categories.

Table 3 Established grades for the quality categories of potato chips

Category	Acceptability (Desirability)	Colour/Grade
000	non-desirable	3
00	non-desirable	3
0	still acceptable	2
1	desirable	1
2	still acceptable	2
3	non-desirable	3
4	non-desirable	3

We recommend investigation into the development of colour charts for certain components that exhibit large colour changes, in particular those that are lighter in colour, such as tropical fruit and milk products. Variability in how individuals perceive the same colour is an inherent problem with this style of evaluation; a panel of >30 individuals may be required. Research is recommended to investigate correlation, of perceived sensory colour change with instrumentally measured colour data for light coloured components.

3.1.4 Establishing Uniformity in Initial Samples

Typically, there are slight batch to batch variations in the colour of a product. Therefore, it may be difficult to set definite colour values in the specification. Permitting the use of a tolerance (or tolerable range) would take into account these variations.

Researchers (Chen and Chui, 1997; Nieto-Sandoval et al., 1999; Oliver et al., 1992) have proposed product-specific colour indices, which allows for a direct correlation with a specific food.

A process could be adopted that would assist in determining the acceptability of a product based on colour change (as illustrated in Figure 8). However any decision to set ranges for these components should include information obtained during sensory evaluations, and as such would give guidance to the point during the storage period that a component becomes unacceptable based on colour.

3.2 Determining Performance Criteria based on Colour

TCD is considered to provide a basis for the establishment of colour-based performance criteria for CRP components where the change may be great and associated with reduced acceptability. Certain CRP components such as SCM and cereal bars become visibly darker during storage. As these foods darken, a burnt flavour can develop, becoming more intense as the level of darkness increases. If the change is proportional, it may be possible to use the knowledge of this relationship to establish a predictive model, designed to anticipate acceptability based solely on L*a*b* values.

Furthermore, the same approach could be adopted, if a linear relationship is discovered for colour and texture or colour and flavour. Current sensory evaluation of CRP components broadly covers the sensory attribute of 'appearance', without focusing on colour specifically. For this to be included in future sensory evaluations a colour scale with well-defined descriptions or colour chips at each interval would need to be established.

We recommend the use of the CIE L*a*b* TCD value as a measure to ensure colour change of CRP components remains within acceptable limits during the warranty period.

3.3 Determining Acceptance Criteria based on Colour

For TCD to be utilised as an effective measure of colour quality for a component, it is necessary for baseline L*a*b* values to be established. Not doing so could potentially enable supply of poor or inferior product. Components that are uncharacteristically dark in colour initially may still be acceptable at the 'end of warranty', as the TCD would not necessarily fall into the high category despite the colour being unacceptably dark.

A ration component at 'time 0' ('initial') should have a colour value that falls within a set of limits. To establish limits, or tolerances, for baseline L*a*b* values, a range of products representative of the component would be required. This would ensure the baseline encompasses products that may be included in future CRP builds.

To establish such a baseline, CRP components and similar commercial-off-the-shelf products would be required. For example; if L* value for 'brand x' was measured as 70.23, 'brand y' was 68.12 and 'equivalent CRP (z)' = 72.94, then a baseline could be determined as follows:

$$\therefore \mathrm{L} * mean = \frac{\mathrm{x} + \mathrm{y} + \mathrm{z}}{n}$$

$$\mathrm{L} * mean = \frac{70.23 + 68.12 + 72.94}{3}$$

$$\mathrm{L} * mean = 70.43$$

Therefore, a specification requirement could be set such that 'Sweetened condensed milk (SCM) must have an initial L* value of not less than 65 and not great than 75.' The current in-service SCM has an initial L* value of 72.17, and would therefore, in this case, fall within the acceptable tolerance range.

We recommend the establishment of baseline L*a*b* values and colour tolerance range as acceptance criteria for new and existing CRP components.

3.4 Data Not Included in this Report

3.4.1 Complete Statistical Analyses

The output of statistical analysis of the colour profiles of CRP components has not been included in this report due to the large volume of information generated. Summarised colour data for all components is presented in Appendix C, while spreadsheets containing the complete statistically analysed colour data for each storage profile are available from the authors on request.

3.4.2 Y-Bright or Yellowness Data

Y-Bright or Yellowness index data is also available from the authors on request. Yellowness is associated with scorching, soiling and general product degradation by light, chemical exposure and processing. Yellowness indices are used chiefly to quantify these types of degradation with a single value. The statistical analysis for Y-bright values may be useful for setting performance criteria for specific CRP components, however, as L* serves as a more useful indicator of colour change, this has been the focus of this report.

3.5 Considerations for CRP Component Manufacturers using Colour Measuring Instruments

L*a*b* is not device dependent, making testing for compliance against future specifications accessible to vendors/product manufacturers, using relatively cheap colour measuring devices. There is a variety of colour measurement instrumentation available, including hand held and benchtop models. There are several companies that produce colour instrumentation including Konica, Minolta, HunterLab or Shimadzu. There are also differences in how colour measurements are reported based on different colour indices of the same product. In a recent review of publications using colour measurement, the majority of articles did not include information on the type of light source (Pathare et al, 2013). Therefore, there is a need to standardise all instrumental measurement parameters to improve transferability between manufacturers and Capability Acquisition and Sustainment Group (CASG) technical authority.

4. Conclusions

Based on analytical data it was concluded;

- The L*a*b* TCD value can be used to establish performance criteria for certain CRP components.
- Further research is required to establish TCD performance criteria.
- Baseline acceptance criteria are needed to support the use of TCD performance criteria.
- Colour charts could be established (using sensory panellists) to reflect a more objective score for component colour acceptability.

5. Recommendations

We recommend that CASG adopt CIE L*a*b* TCD values as a measure to ensure colour changes of CRP components remain within acceptable limits.

Implementation of this recommendation should be based on further research to:

- Establish baseline L*a*b* values and colour tolerance ranges for new and existing CRP components.
- Adopt the CIE L*a*b* TCD value as a measure to ensure colour change of CRP components remains within acceptable limits during the warranty period.
- Develop visual colour assessment charts to establish colour tolerances for use during sensory analysis for components that exhibit large colour changes.
- Investigate correlation of perceived sensory colour change with instrumentally measured colour data for light coloured components.

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Appendix A Storage Profiles and CRP Components

Table A1 Storage profiles for CRP food items

Storage profile	Storage time	Storage temperature
1	Initials	Initial
2	2 weeks	50 °C
3	4 weeks	50 °C
4	6 weeks	50 °C
5	8 weeks	1 °C
6	8 weeks	50 °C
7	10 weeks	50 °C
8	12 weeks	50 °C
9	3 months	40 °C
10	6 months	1 °C
11	6 months	30 °C
12	6 months	40 °C
13	9 months	40 °C
14	12 months	1 °C
15	12 months	20 °C
16	12 months	30 °C
17	12 months	40 °C
18	18 months	30 °C
19	24 months	1 °C
20	24 months	20 °C
21	24 months	30 °C

Note: Control samples, i.e. 'Initials,' were analysed to capture the original quality of the product and to provide a baseline for determining changes during storage. Where data was unavailable for the 'initials', storage profile 5 was used instead (1 °C for 8 weeks).

Table A2 Components evaluated for colour

Ration packing program		
08/09	**09/10**	**10/11**
Chicken noodles	Cream cracker	Tuna in spring water
Chicken flavouring	Plain sweet	Chicken curry
Beef noodles	Scotch finger	Curry sausage & vegetables
Beef flavouring	Crisp bread	Chilli con carne
Peaches	Apricot & coconut muesli bar	Beef teriyaki
Pears	Forest fruits muesli bar	Carrots
Two fruits	Tropical muesli bar	Green peas
Tuna: tomato & basil	Fruitful muesli	Sweet corn
Rice	Natural muesli	Cream of chicken soup
Baked beans	Cheddar cheese	Tomato soup
Potatoes	Sweetened condensed milk	Savoury soup
Salmon & pasta	Skim milk powder	Lemon/lime sports drink
Vegetable curry	Fruit pudding	Grape sports drink
Beef minced tortellini	Chocolate pudding	Orange sports drink
Sausage & vegetables	Chocolate pudding sauce	Chocolate candies
Beef meatballs	Golden pudding	Sweet chilli sauce
BBQ chicken	Golden pudding sauce	Tomato ketchup
Beef soup powder	Raspberry fruit spread	Marmalade
Savoury vegetable soup powder	Vegetable/yeast spread	Plum fruit spread
Chocolate ration	Chocolate drink powder	Strawberry fruit spread
M&M's	Instant coffee	Braised beef & gravy
Chocolate spread	Apricot fruit grains	
White chocolate spread	Raspberry fruit grains	
	Mixed berry fruit grains	
	Strawberry fruit grains	
	Tropical fruit grains	
	BBQ sauce	
	Chilli sauce	
	Tomato ketchup	
	Worcestershire sauce	
	Black pepper	

Appendix B Calculations and Equations

B.1 Change of L*a*b* colour in CRP components

Colour differences for CRP components were calculated by subtracting the L*a*b* values measured at 2 years at 30 °C from the control samples, as expressed below:

$\Delta \boldsymbol{L^*} = L^*_{sample} - L_{control}$. Positive ΔL^* numbers will be lighter than the control, and negative ΔL^* numbers will be darker.

$\Delta \boldsymbol{a^*} = a^*_{sample} - a^*_{control}$. Positive Δa^* numbers will be more red (or less green), and negative Δa^* numbers will be more green (and less red).

$\Delta \boldsymbol{b^*} = b^*_{sample} - b^*_{control}$. Positive Δb^* numbers will more yellow (or less blue), and negative Δb^* numbers will be more blue (or less yellow).

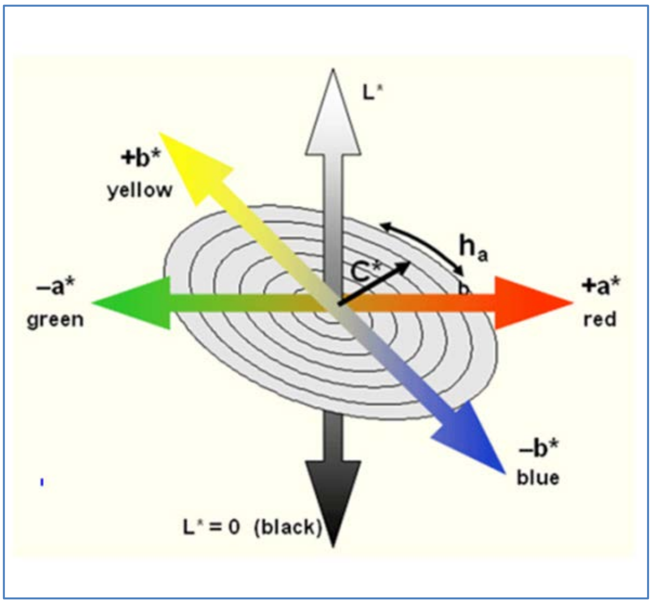

*Figure A1 Illustration of chroma, hue and L*a*b* values within 3D colour space*

B.2 Hue Angle

Point X is the plot of 'a*' and 'b*' for a particular food. The angle from the start of the +a axis to point X is referred to as the Hue angle (H) and is calculated using the following equation.

$$\boldsymbol{H = tan^{-1}\frac{a^{*2}}{b^{*2}}}$$

$\Delta H^* = H^*_{sample} - H^*_{standard}$. Positive ΔH^* numbers indicate the hue angle is in the counter clockwise direction from the standard, and negative numbers are in the clockwise direction. If the standard has a H of 90°, a positive ΔH is a shift in the green direction, and a negative ΔH number is a shift in the red direction.

B.3 Chroma

$\Delta C^* = C^*_{sample} - C^*_{standard}$. Positive ΔC^* numbers mean the sample has greater intensity or is more saturated, and negative ΔC^* numbers will mean that the sample is less saturated.

$$\boldsymbol{C = \sqrt{a^{*2} + b^{*2}}}$$

B.4 Total Colour Difference

TCD (also reported as ΔE) factors in the combined changes or movement of the L*a*b* values for CRP components within three dimensional spaces. This measure provides information as to whether the observed change in the colour of a product is true. The TCD also factors in the Hue angle (H), which is the angle that a line joining the point in Hunter space with the origin makes with the horizontal axis (Figure B1). However, as the H changes dramatically for small differences in neutral and near-neutral colours, use of ΔH^*ab hue difference is not recommended when $C^* < 5$. In this case, ΔL^*, Δa^*, and Δb^* should be used instead to define colour differences. The C is also factored in to the TCD value and indicated the saturation intensity.

TCD (ΔE) is calculated by the following equation:

$$\boldsymbol{\Delta E^*_{ab} = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}}$$

Appendix C Colour Results and Calculations for Ration Components at the End of Warranty

Table C1 Colour change in 08/09 combat ration components after 2 years of storage at 30°C

Component	L* a* b*	L*a*b* Mean (2yrs/30°C)	±SD	Sig. (P Value)	Δ L*a*b*	Δ C	Δ H	Δ E (TCD)
Baked beans	L*	41.46	0.40	0.000	-4.12	-4.27	-0.021	5.94
	a*	14.05	0.07	0.000	-2.81			
	b*	18.97	0.40	0.000	-3.23			
BBQ chicken	L*	47.03	0.58	0.000	-4.50	-3.70	0.030	5.86
	a*	12.48	0.38	0.001	-1.11			
	b*	23.11	0.58	0.000	-3.59			
Beef & meatballs	L*	46.36	0.54	0.002	-1.61	-3.66	0.026	4.03
	a*	11.09	0.15	0.028	-1.35			
	b*	19.56	0.35	0.000	-3.44			
Beef minced Tortellini	L*	50.65	0.70	0.339	0.54	0.16	0.001	0.56
	a*	14.36	0.19	0.640	0.10			
	b*	23.69	0.59	0.830	0.12			
Beef llavouring, from noodles	L*	56.25	1.67	0.146	-2.65	-1.40	-0.014	3.01
	a*	5.30	0.09	0.306	-0.74			
	b*	12.61	0.28	0.214	-1.21			
Beef noodles	L*	84.49	0.85	0.016	-1.37	0.001	3.70	3.95
	a*	0.84	0.18	0.003	0.37			
	b*	19.42	0.50	0.000	3.69			
Beef soup	L*	74.68	0.45	0.000	-3.83	4.69	0.003	6.05
	a*	3.38	0.05	0.000	1.15			
	b*	14.21	0.10	0.000	4.55			
Chocolate spread	L*	45.29	1.81	0.002	12.03	-11.37	0.315	16.78
	a*	7.67	0.88	0.039	-4.65			
	b*	8.24	1.25	0.095	-10.74			
Chicken flavouring, from noodles	L*	73.06	0.59	0.000	-3.52	2.92	0.000	4.58
	a*	0.87	0.21	0.573	0.09			
	b*	20.07	0.35	0.004	2.92			
Chicken noodles	L*	85.97	0.78	0.222	-0.66	-0.15	-0.002	0.78
	a*	0.42	0.02	0.000	-0.38			
	b*	16.80	0.11	0.430	-0.14			
M & M's	L*	61.25	0.26	0.045	4.94	1.85	-0.051	5.32
	a*	5.77	1.03	0.649	0.20			
	b*	13.23	0.97	0.198	1.95			

Component	L* a* b*	L*a*b* Mean (2yrs/30°C)	±SD	Sig. (P Value)	Δ L*a*b*	Δ C	Δ H	Δ E (TCD)
Peaches	L*	56.00	1.33	0.075	3.96	4.51	-0.058	7.09
	a*	8.57	0.73	0.043	-2.49			
	b*	39.40	2.16	0.073	5.33			
Pears	L*	55.99	1.65	0.519	-1.24	6.25	-0.070	6.66
	a*	-1.55	0.27	0.049	0.81			
	b*	14.77	1.19	0.004	6.50			
Potatoes	L*	75.75	2.37	0.001	-4.39	0.29	0.000	4.41
	a*	-0.06	1.28	0.605	-0.30			
	b*	12.21	0.86	0.543	0.29			
Ration chocolate	L*	64.22	4.00	0.106	-5.11	2.14	0.021	5.55
	a*	7.44	0.22	0.000	1.18			
	b*	16.00	1.68	0.124	1.81			
Rice	L*	78.50	0.64	0.004	-1.88	0.93	-0.007	2.19
	a*	0.69	0.08	0.022	-0.55			
	b*	13.56	0.23	0.084	0.97			
Salmon & pasta	L*	65.94	0.38	0.001	-4.20	0.53	-0.007	4.24
	a*	9.41	0.88	0.995	0.01			
	b*	23.75	0.67	0.529	0.57			
Sausage & vegetables	L*	52.97	0.65	0.008	-1.47	-2.12	0.045	2.78
	a*	14.61	0.23	0.729	-0.10			
	b*	25.46	0.34	0.001	-2.36			
Savoury vegetable soup	L*	60.19	1.86	0.001	-6.13	-5.76	-0.043	8.43
	a*	4.56	0.04	0.000	-2.90			
	b*	10.85	0.25	0.000	-5.01			
Tuna with tomato and basil	L*	49.87	0.76	0.000	-2.80	1.07	0.183	4.89
	a*	14.19	0.62	0.000	3.92			
	b*	22.79	0.32	0.002	-0.85			
Two rruits	L*	54.97	1.15	0.029	5.61	6.07	-0.036	8.61
	a*	4.85	0.41	0.069	-1.15			
	b*	30.65	0.95	0.012	6.42			
Vegetable curry	L*	52.56	0.19	0.000	-1.07	-6.21	-0.007	6.31
	a*	10.24	0.99	0.017	-2.30			
	b*	31.24	0.61	0.000	-5.77			
White chocolate spread	L*	77.48	0.21	0.312	0.20	-2.99	0.000	2.99
	a*	1.04	0.25	0.510	-0.15			
	b*	17.36	0.27	0.000	-2.98			

Table C2 Colour change in 09/10 combat ration components after 2 years of storage at 30°C

Component	L* a* b*	L*a*b* Mean (2yrs/30°C)	±SD	Sig. (P Value)	Δ L*a*b*	Δ C	Δ H	Δ E (TCD)
Apricot & coconut muesli bar	L*	68.43	2.23	0.009	6.67	-0.14	-0.049	6.85
	a*	5.33	0.84	0.039	-1.51			
	b*	20.11	1.54	0.760	0.31			
Apricot fruit grain	L*	40.18	0.45	0.001	-6.97	-15.33	0.587	16.89
	a*	0.70	0.10	0.000	-10.63			
	b*	0.32	0.10	0.000	-11.11			
BBQ sauce	L*	26.35	0.50	0.020	-1.09	-1.34	0.045	1.72
	a*	0.72	0.04	0.000	-1.05			
	b*	0.52	0.37	0.018	-0.83			
Black pepper	L*	57.44	0.75	0.014	1.96	1.24	-0.005	2.34
	a*	1.47	0.10	0.345	-0.06			
	b*	12.18	0.38	0.005	1.26			
Cheddar cheese	L*	76.55	0.54	0.000	-9.70	2.48	0.088	11.15
	a*	7.50	0.16	0.000	5.32			
	b*	23.96	0.39	0.017	1.44			
Chilli sauce	L*	28.54	0.28	0.000	-4.34	-9.78	-0.081	10.70
	a*	3.83	0.33	0.000	-8.05			
	b*	3.05	0.48	0.000	-5.56			
Chocolate drink powder	L*	57.91	0.17	0.002	-0.89	-0.50	0.012	1.03
	a*	8.52	0.25	0.355	-0.15			
	b*	13.58	0.12	0.002	-0.49			
Chocolate pudding (cake)	L*	45.28	1.04	0.001	8.05	-2.80	0.018	8.52
	a*	7.83	0.44	0.003	-1.72			
	b*	9.11	1.35	0.061	-2.22			
Chocolate pudding (sauce)	L*	27.69	0.31	0.004	1.41	0.08	-0.130	1.46
	a*	3.53	0.34	0.710	-0.13			
	b*	2.41	0.54	0.448	0.35			
Cream cracker biscuit	L*	81.95	0.79	0.283	0.80	-1.82	-0.002	1.99
	a*	3.16	0.08	0.029	-0.44			
	b*	21.00	0.51	0.007	-1.77			
Crispbread	L*	71.22	0.57	0.028	-1.31	-0.37	0.002	1.37
	a*	4.85	0.25	0.943	0.01			
	b*	20.69	0.30	0.152	-0.39			
Forest fruits muesli bar	L*	63.23	0.64	0.848	-0.11	-1.00	0.002	1.00
	a*	6.88	0.29	0.206	-0.27			
	b*	20.39	0.37	0.039	-0.96			
Fruitful muesli	L*	75.74	0.59	0.000	9.42	-0.48	-0.031	9.50
	a*	4.77	0.08	0.000	-1.22			
	b*	20.08	0.11	0.803	-0.17			

Component	L* a* b*	L*a*b* Mean (2yrs/30°C)	±SD	Sig. (P Value)	Δ L*a*b*	Δ C	Δ H	Δ E (TCD)
Fruit pudding (inside cake)	L*	40.58	0.46	0.003	7.79	-19.33	0.612	21.32
	a*	4.47	0.78	0.000	-6.61			
	b*	4.23	1.19	0.000	-18.72			
Golden pudding (cake)	L*	57.14	0.64	0.000	7.70	-2.66	0.004	8.15
	a*	10.13	0.57	0.072	-0.94			
	b*	23.61	0.81	0.021	-2.49			
Golden pudding (sauce)	L*	57.96	1.95	0.000	26.39	14.35	-0.163	30.12
	a*	11.62	0.62	0.001	4.94			
	b*	24.01	1.64	0.000	13.65			
Instant coffee	L*	44.55	0.30	0.000	-3.30	-2.29	0.113	4.14
	a*	9.37	0.17	0.005	-0.60			
	b*	11.47	0.30	0.000	-2.43			
Mixed berry fruit grain	L*	38.42	0.43	0.464	-0.25	-6.41	0.117	6.43
	a*	0.43	0.11	0.000	-6.03			
	b*	0.02	0.11	0.000	-2.22			
Natural muesli	L*	79.81	0.44	0.886	0.20	0.42	-0.005	0.50
	a*	2.83	0.20	0.784	-0.09			
	b*	14.78	0.36	0.252	0.45			
Plain sweet biscuit	L*	74.74	0.98	0.026	2.98	-0.80	-0.022	3.21
	a*	5.73	0.35	0.020	-1.06			
	b*	22.32	0.33	0.073	-0.53			
Raspberry fruit grain	L*	39.37	0.18	0.000	-1.66	-7.71	0.261	7.92
	a*	0.77	0.26	0.000	-6.60			
	b*	0.18	0.20	0.000	-4.05			
Scotch finger biscuit	L*	77.20	0.99	0.388	0.95	-1.99	-0.014	2.34
	a*	4.16	0.39	0.022	-1.16			
	b*	22.54	0.27	0.002	-1.79			
Skim milk powder	L*	94.08	0.08	0.835	0.02	-0.92	-0.015	1.23
	a*	-2.75	0.19	0.002	0.96			
	b*	18.50	0.66	0.136	-0.77			
Strawberry fruit grain	L*	38.99	0.44	0.002	-2.46	-7.22	0.079	7.63
	a*	1.01	0.15	0.000	-5.89			
	b*	0.63	0.16	0.000	-4.18			
Sweetened condensed milk	L*	55.66	0.39	0.000	-16.51	8.02	0.111	19.72
	a*	8.69	0.09	0.000	8.51			
	b*	26.02	0.17	0.000	6.61			
Tomato ketchup	L*	29.12	0.47	0.002	-1.90	-5.45	0.068	5.78
	a*	5.06	0.31	0.000	-4.07			
	b*	3.84	0.42	0.000	-3.64			

Component	**L* a* b***	**L*a*b* Mean (2yrs/30°C)**	**±SD**	**Sig. (P Value)**	**Δ L*a*b***	**Δ C**	**Δ H**	**Δ E (TCD)**
Tropical fruit grains	L*	38.73	0.40	0.000	-8.42	-15.22	0.505	17.44
	a*	0.98	0.12	0.000	-8.76			
	b*	0.79	0.12	0.000	-12.51			
Tropical muesli bar#	L*	59.72	-	-	-2.26	0.52	0.018	2.37
	a*	7.75	-	-	0.65			
	b*	21.12	-	-	0.33			
Vegetable yeast spread	L*	26.22	0.26	0.000	-1.79	0.28	-0.087	1.82
	a*	2.20	0.05	0.320	0.06			
	b*	2.71	0.13	0.021	0.31			
Worcestershire sauce	L*	26.22	0.43	0.283	-0.68	-0.11	-0.051	0.69
	a*	0.65	0.13	0.816	-0.09			
	b*	0.69	0.40	0.926	-0.06			

#Insufficient data to calculate ±SD and Sig. P Value

Table C3 Colour change in 10/11 combat ration items after 2 years of storage at 30°C

Component	L* a* b*	L*a*b* Mean (2yrs/30°C)	±SD	Sig. (P Value)	Δ L*a*b*	Δ C	Δ H	Δ E (TCD)
Beef teriyaki	L*	42.40	0.76	0.000	-3.47	-0.32	0.053	3.61
	a*	9.75	0.25	0.000	0.69			
	b*	18.26	0.52	0.038	-0.71			
Braised beef & gravy	L*	50.72	0.90	0.024	-1.39	0.77	0.035	1.70
	a*	9.91	0.29	0.000	0.89			
	b*	18.73	0.68	0.110	0.41			
Carrots	L*	43.62	0.24	0.001	-0.89	0.42	0.147	2.60
	a*	22.47	0.27	0.000	2.08			
	b*	23.32	0.33	0.000	-1.29			
Chicken curry	L*	59.72	0.69	0.000	-2.89	-0.59	0.041	3.94
	a*	7.05	0.08	0.000	2.43			
	b*	26.96	0.68	0.008	-1.12			
Chilli con carne	L*	43.54	0.36	0.000	-1.18	-0.21	-0.006	1.20
	a*	11.79	0.32	0.155	-0.18			
	b*	16.98	0.42	0.461	-0.13			
Chocolate candies	L*	60.32	2.25	0.000	4.81	1.35	-0.135	5.16
	a*	6.63	0.80	0.483	-0.40			
	b*	12.48	1.72	0.015	1.81			
Cream of chicken soup	L*	83.64	0.55	0.000	-1.70	-1.24	0.001	2.54
	a*	0.91	0.15	0.000	1.41			
	b*	29.11	0.32	0.001	-1.25			
Curry sausages & vegetable	L*	56.17	0.30	0.188	-0.42	-1.92	0.009	2.38
	a*	3.99	0.50	0.000	1.12			
	b*	30.90	0.28	0.000	-2.06			
Grape sports drink	L*	50.29	1.46	0.000	-4.90	-1.07	-0.058	5.01
	a*	-3.50	0.23	0.000	0.97			
	b*	-2.56	0.08	0.000	0.48			
Green peas	L*	48.36	0.45	0.000	3.14	1.28	0.001	3.39
	a*	2.30	0.08	0.000	0.28			
	b*	21.68	0.69	0.004	1.25			
Lemon/Lime sports drink	L*	81.93	2.53	0.014	-4.60	0.42	-0.079	6.32
	a*	-1.87	0.72	0.000	4.16			
	b*	21.70	1.92	0.574	1.21			
Marmalade	L*	36.43	0.30	0.000	-4.57	-4.17	0.100	6.65
	a*	6.18	0.25	0.000	1.00			
	b*	14.92	0.33	0.000	-4.73			

Component	L* a* b*	L*a*b* Mean (2yrs/30°C)	±SD	Sig. (P Value)	Δ L*a*b*	Δ C	Δ H	Δ E (TCD)
Orange sports drink	L*	68.04	1.48	0.000	-3.71	1.55	0.020	4.04
	a*	27.68	1.12	0.007	1.43			
	b*	23.11	1.13	0.076	0.71			
Plum fruit spread	L*	27.01	0.52	0.000	-3.86	-5.64	-0.114	6.85
	a*	2.59	0.30	0.000	-4.59			
	b*	2.27	0.33	0.000	-3.30			
Savoury soup	L*	59.49	1.35	0.000	-10.49	-2.22	0.005	10.72
	a*	5.22	0.15	0.000	-0.82			
	b*	12.05	0.48	0.000	-2.07			
Strawberry fruit spread	L*	28.48	0.37	0.001	-2.38	-4.06	-0.361	4.98
	a*	4.31	0.26	0.000	-4.29			
	b*	3.73	0.43	0.071	-0.89			
Sweet chilli sauce	L*	26.17	0.48	0.000	-1.64	-5.80	0.032	6.03
	a*	3.08	0.66	0.000	-4.78			
	b*	1.97	0.50	0.000	-3.30			
Sweet corn	L*	61.43	0.52	0.000	-4.08	-1.68	0.025	4.74
	a*	7.21	0.43	0.000	1.35			
	b*	29.75	1.02	0.001	-2.00			
Tomato ketchup	L*	28.20	0.48	0.000	-2.76	-6.42	-0.101	7.00
	a*	3.87	0.20	0.000	-5.16			
	b*	3.49	0.17	0.000	-3.84			
Tomato soup	L*	63.19	1.29	0.000	-5.86	-3.88	-0.070	7.19
	a*	5.68	0.16	0.000	-2.86			
	b*	16.55	0.87	0.000	-3.05			
Tuna in spring water	L*	60.11	0.83	0.000	1.99	1.09	0.010	2.28
	a*	7.01	0.29	0.002	0.59			
	b*	16.96	0.72	0.010	0.93			

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16. DELIBERATE ANNOUNCEMENT

No limitations

17. CITATION IN OTHER DOCUMENTS

Yes

18. RESEARCH LIBRARY THESAURUS

Combat rations, Sensory, Total colour difference, Quality assurance

19. ABSTRACT

The Australian Department of Defence standard DEF(AUST) specifications for combat ration pack (CRP) food components include functional and performance criteria to ensure that components procured are suitable for their intended purpose. Sensory analysis of appearance does not provide an objective basis for decisions to be made on product colour acceptability. The human perception of colour is subjective and varies among individuals, whereas instrumental methods provide objective data. Instrumental colour analysis information collected during storage trials has been reviewed and considered as an alternative for developing performance criteria for CRP components. There were significant changes in the colour values of some CRP components during the two year storage period. Correlation of this data with the results of sensory evaluations could support the development of CRP performance criteria based on colour.