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Quality Assurance of Current Combat Ration Pack Components: 12 Months Progress Report on 2010/11 Ration Packing Program

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ABSTRACT

DSTO provides science and technology support to DMO for the through-life management of combat ration pack components. This report details the performance of 24 components from the 2010/11 ration packing program following 12 months storage under controlled conditions. The results provide guidance as to the anticipated shelf life of each component and the ability of products to meet warranty requirements. The report concludes that 5 components are expected to meet the warranty requirements, 11 are at risk of failure and 8 have either already failed or are expected to fail.

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Executive Summary

The Defence Science and Technology Organisation (DSTO) provides science and technology (S&T) support to the Defence Materiel Organisation (DMO) for the through-life management of combat ration pack (CRP) components.

DSTO's support includes provision of quality assurance (QA) testing of current CRP components. This report details the performance of 24 components from the 2010/11 ration packing program following 12 months storage under controlled conditions.

The results relate to changes over time of physical, visual and sensory measures, providing guidance as to the anticipated shelf life of each component and the ability of products to meet the warranty requirement that components remain suitable for use following up to 24 months storage at 30 °C.

The following components are expected to meet the warranty requirements: Chilli Con Carne, Plum Fruit Spread, Strawberry Fruit Spread, Lemon/Lime Sports Powder and Peppermint Candy.

Those at risk of not achieving warranty are: Tuna in Springwater, Beef Teriyaki, Green Peas, Cream of Chicken Soup, Marmalade, Orange Sports Powder, Grape Sports Powder, Banana Berry Candy, Musk Candy, Tomato Ketchup and Sweet Chilli Sauce.

Components that have either failed or are likely to fail to achieve warranty are: Braised Beef & Gravy, Chicken Curry, Curried Sausages & Vegetables, Sweet Corn, Carrots, Savoury Soup, Tomato Soup and Chocolate Candy.

The report makes recommendations to improve initial acceptability and to reduce the likelihood of failure during storage through reformulation, repackaging or replacement of current products. The recommendations are provided in more detail in the body of the report.

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1. Introduction

The Combat Rations Fleet within Defence Materiel Organisation (DMO) "is required to deliver continuous capability through acquisition and sustainment of combat rations and ancillaries for the ADF" (Department of Defence, 2008a). The Defence Science and Technology Organisation (DSTO) provides science and technology (S&T) support to through-life management of combat ration pack (CRP) components.

DSTO's support includes provision of quality assurance (QA) testing of current CRP components. This may be viewed as consisting of three stages as follows:

- Determine initial compliance and nutritional composition
- Conduct shelf life (SL) monitoring and review at 12 months
- Determine nutritional composition at 24 months and conduct warranty[1] verification.

The results of the initial compliance and nutritional composition evaluation have been reported (De Diana and Coad, 2012).

This report details the performance of 24 components from the 2010/11 ration packing program following 12 months storage under controlled conditions. The results relate to changes over time of physical, visual and sensory measures, providing guidance as to the anticipated SL of each component and the ability of products to meet warranty requirements.

A detailed report on overall compliance and performance will be provided following 24 months storage.

[1] Combat ration components are to remain suitable for use following storage for up to 24 months at 30 ^{o}C. The warranty requirement and period has not been consistently expressed in relevant documentation (Department of Defence, 2008b, 2009a, 2009b). However, a process of updating and converting product specifications into the DEF(AUST) format is nearing completion and the revised specifications include a clear statement of this requirement.

2. Materials and Methods

2.1 Sampling and Testing Regime

Anticipated primary modes of deterioration (Appendix A) with potential to result in loss of product quality were determined following consideration of:

- Product formulation and processing techniques
- Chemical characteristic of the food
- Sensory quality
- Physical structure and mechanical strength of foods and/or packaging
- Permeability of packaging.

On the basis of the anticipated modes of deterioration and specified requirements (Department of Defence, 2008b) a suite of quality measurands was established for monitoring product stability and verifying warranty.

A sampling plan for the testing program was developed taking into account the following factors:

- Sample homogeneity/heterogeneity, to ensure representative sampling
- Number of storage variables (time/temperature points)
- Sample size requirements for testing
- Number of replicates required based on the nature and complexity of each test
- Defined sampling requirements for microbiological examinations/tests
- Cost of samples and tests.

Appendix B details the sampling and testing regime for the sensory, physical and visual assessments. A summary of the methods of analysis is provided at Appendix C[2].

2.2 Procurement, Initial Assessment and Storage of CRP Items

The storage history of samples prior to receipt at DSTO was unknown and assessment of any quality loss between manufacture and receipt was not possible.

For the purpose of SL testing, the samples received by DSTO were assumed to be representative of the components ultimately delivered to DMO. Samples were labelled with ID numbers before undergoing analysis and/or storage trials. The initial assessment was undertaken and reported (De Diana and Coad, 2012).

[2] Full details of methodology can be provided upon request. All testing was conducted by DSTO-Scottsdale. Although not National Association of Testing Authorities accredited, the test procedures have been developed specifically for the testing and evaluation of CRP components.

Prior to the commencement of the SL storage trial, individual CRP components were screened for packaging integrity. This included visual inspection and leak testing where applicable. Only packages that passed packaging integrity screening were placed on storage.

2.3 Storage Profile

Table 1 shows the storage profile[3] that was adopted for real time (20 °C and 30 °C) and accelerated shelf life testing (ASLT) (40 °C and 50 °C). Control samples were held at 1–4 °C. This profile provides for collection of data at time/temperature points suited to monitoring the modes of deterioration of interest (DEF(AUST) 10663). Relative humidity was controlled at 50% in the 50 °C storage chamber, but not at other temperatures as those chambers were not equipped with humidity control[4].

Table 1: Storage profile for warranty verification and shelf life assessment

Temp	Initial	Time												
		Weeks					Months							
		2	4	6	8	10	3	6	9	12	18	24	36	48
1-4°C					✓			✓		✓		✓		✓
20°C	✓									✓		✓	✓	✓
30°C								✓		✓	✓	✓		
40°C							✓	✓	✓	✓				
50°C		✓	✓	✓	✓	✓	✓							

✓ Indicates points in the storage trial at which samples were removed for testing.

2.4 Acceptance Criteria and Interpretation of Results

Performance criteria currently exist within Australian Defence Force Food Specifications (ADFFS) (Department of Defence, 2008b)—Part A and the Food Standards Code (FSC) (FSANZ, 2000) for initial product compliance only. Performance criteria for the assessment of SL or end of warranty requirements are not specified in the ADFFS[5].

In the absence of performance criteria, predictions drawn in this report were based on sensory acceptability data and trends in physical and instrumental data. Products with Hedonic Ratings of less than 5 for overall acceptability were deemed 'unacceptable', those with ratings

[3] The profile runs to 48 months to enable the collection of data for the estimation of shelf life and rates of deterioration for improved understanding of the relevant processes.

[4] Humidity control will be available when DSTO moves into its new laboratory facility in late 2013.

[5] This is being addressed in the current process of updating and converting product specifications into the DEF(AUST) format. The revised specifications include performance criteria that are applicable upon receipt and throughout the warranty period.

between 5 and 6.49 were ranked 'marginal' and those with ratings of 6.5 and above were regarded as 'acceptable'[6].

The results and predictions should be interpreted with a degree of caution as the sensory panels are small and do not represent the consumer demographic, the storage trials are not complete and a statistical analysis has not been undertaken. The conclusions and recommendations are intended to provide an early guide and potential responses to likely outcomes.

[6] DMO and DSTO have historically used these criteria, however they have not yet been formalised.

3. Results and Discussion

At the completion of each storage profile, visual inspection of all packaging was conducted. In all cases package integrity was found to have been maintained during storage.

A summary of sensory overall acceptability ratings is provided in Table 2. At the completion of 12 months storage at 30 °C, six products rated 'pass', ten 'marginal' and eight 'fail'. In addition, based on the sensory results, this table provides forecasted performance against warranty requirements. It is recommended that products that have already failed, or have been forecast as at risk of failing, be investigated with consideration given to reformulation, repackaging or replacement.

Table 2. Results Summary - Sensory Evaluation for Overall Acceptability

Product	Initial	12wks	12Mnth				Warranty
		50°C	1°C	20°C	30°C	40°C	Expectation
Tuna in Springwater	P	M	M	M	M	M	P
Beef Teriyaki	M	F	P	M	M	F	AR
Braised Beef & Gravy	M	F	F	F	F	F	F
Chicken Curry	M	F	M	M	F	F	F
Chilli Con Carne	P	M	P	P	P	M	P
Curried Sausages & Vegetables	P	M	M	M	F	F	F
Carrots	F	F	F	F	F	F	F
Green Peas	P	M	M	M	M	F	AR
Sweet Corn	M	F	M	F	F	F	F
Marmalade	P	F	P	P	M	F	AR
Plum Fruit Spread	P	F	P	P	P	F	P
Strawberry Fruit Spread	P	M	P	P	P	F	P
Chocolate Candy	M	F	F	F	F	F	F
Banana Berry Candy	P	M	M	M	M	P	AR
Musk Candy	P	M	M	M	P	M	AR
Peppermint Candy	P	M	P	P	P	P	P
Grape Beverage	P	M	M	M	M	M	AR
Lemon/Lime Beverage	P	F	P	P	P	M	P
Orange Sports Beverage	P	M	P	P	M	F	AR
Cream of Chicken Soup	P	F	P	P	M	F	AR
Savoury Soup	P	F	P	M	F	F	F
Tomato Soup	P	M	M	F	F	F	F
Sweet Chilli Sauce	M	M	P	M	M	F	AR
Tomato Ketchup	P	M	P	P	M	F	AR

P - Pass M - Marginal F - Fail AR - At Risk

In the remainder of this section, more detailed results are provided for each component.

3.1 Fish

3.1.1 Tuna in Springwater

The quantitative descriptive analysis (QDA) results for this component support the overall acceptability findings with only minor changes to aroma, appearance and texture over the 12-month storage period.

Water activity and pH remained stable and seal creep was less than 1 mm.

Visual inspection, sensory evaluation of appearance and instrumental measures for colour (CIE L*a*b* colour scale) revealed only minor variations from the initial colour during the 12 months storage period. Visual evidence of colour stability during storage is provided in Figure 1.

Figure 1. Colour of Tuna in Springwater after 12 months storage at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

Based on these results it is expected that this product will remain 'marginal' but will meet warranty requirements.

3.2 Meat Products

3.2.1 Beef Teriyaki

The QDA results record increases in darkness of the meat and sauce. The meat also became chewier and the development of unpleasant fat flavours was observed. Fat and connective tissues were noted as being present in all samples as evidenced by Figure 2.

Figure 2. Fatty tissue in Beef Teriyaki sample.

There were marked decreases in L* and b* for samples stored at elevated temperatures, indicating darkening and decreasing yellow hues, whilst a slight decrease in red hues (a*) was observed in samples at 20 °C and 30 °C. Images of samples following 12 months storage are shown in Figure 3.

Figure 3. Beef Teriyaki after 12 months storage at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

Water activity remained stable at all temperatures, whilst pH decreased slightly over time and with higher storage temperatures. Association between the decrease in pH and overall acceptability will be further investigated at the completion of storage trials.

Based on the sensory results alone, it is not expected that this product will achieve warranty. It is recommended that options to improve product quality and extend stability be explored, including review of product formulation to increase initial acceptability.

3.2.2 Braised Beef and Gravy

The 'overall acceptability' rating was 'unacceptable', which was supported by QDA results for appearance, texture and flavour. A decrease in quality was observed, namely in relation to oiliness of the sauce, chewiness of the meat and development of an unpleasant aftertaste.

Phase separation of the gravy for this product was evident during visual inspection following 9 months of storage (Figure 4).

Figure 4. Phase separation of gravy in Braised Beef and Gravy.

Visual representation of changes to colour following 12 months storage are provided in Figure 5. Trends in the instrumental colour measurements aligned with visual observations. Decreases in L* over time and temperature represent darkening, whilst an increase in developing red hues was indicated with increases of a*. Slight increases in yellow hues (b*) were observed at 50 °C.

Figure 5. Colour changes in Braised Beef & Gravy following 12 months storage at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

Results for water activity and pH at completion of 12 months storage were observed to be unchanged from initial values for all temperatures. Seal creep was less than 1 mm.

These results indicate that this component has already failed and therefore will not achieve the warranty requirements. As the initial acceptability was 'marginal', it is recommended that reformulation be undertaken to improve initial acceptability and reduce the likelihood of failure during storage.

3.2.3 Chicken Curry

Based on the QDA results for this component, there was a decrease in the textural quality of the meat, which became chewier and dryer. Furthermore, a slightly rancid flavour and unpleasant aftertastes developed.

Following 12 months storage, phase separation of the gravy was observed, with darkening and development of redness of the meat. Instrumental colour measurements supported visual observations and sensory appearance results with slight decreases being recorded in L* and b*, representing darkening and yellow hues respectively, at 30 °C and 40 °C; a more prominent decrease was observed at 50 °C. Increases in red hues, represented by a* were observed regardless of storage temperature. Figure 6 illustrates changes in colour and the initial stages of phase separation.

Figure 6. Darkening and reddening of Chicken Curry after 12 months storage at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

Following storage for 12 months, the water activity and pH remained stable at all temperatures. Seal creep was less than 1 mm.

Based on sensory results alone, the Chicken Curry is not expected to achieve warranty. It is recommended that reformulation of this component be investigated to increase the initial acceptability rating and to prolong SL.

3.2.4 Chilli Con Carne

QDA data supports the overall acceptability results with minor variations to aroma, appearance, texture and flavour ratings being observed.

At the completion of 12 months storage, visual inspections of the 1–30 °C samples revealed no changes, however darkening of the meat for samples stored at 40 °C was observed. The instrumental colour results for the 1–30 °C samples remained stable over the storage period to date, therefore supporting the visual and sensory data. The results for samples stored at elevated temperatures recorded minor decreases across the complete colour scale (L*, a* and b*), therefore moving into the brown regions.

Visual representation of Chilli Con Carne following 12 months storage is provided in Figure 7.

Figure 7. Control at 1 °C (a). Chilli Con Carne at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

The water activity and pH remained stable for all samples; seal creep was less than 1 mm.

Based on these results it is expected that the Chilli Con Carne will achieve warranty.

3.2.5 Curried Sausages and Vegetables

QDA results support overall acceptability ratings; all samples provided evidence of decreases in textural quality. Furthermore, darkening of the sauce and sausages was observed along with development of an unpleasant aftertaste.

When samples were opened for evaluation following 12 months storage, the development of unpleasant and/or burnt aromas was noted for all samples. Whilst the vegetables remained characteristic in colour, the sauce had darkened and a red hue had developed in the sausages.

Instrumental colour measurements for the 1 °C and 20 °C samples remained stable; a slight increase in a* was observed for the 30 °C sample after 12 months of storage. The 40 °C sample increased in a* and decreased in both L* and b*, reinforcing visual and sensory observations. Some colour changes are evident in Figure 8.

Figure 8. Colour changes of Curried Sausages and Vegetables at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

The water activity remained stable for all temperatures and storage times. Seal creep was less than 1 mm.

The pH was observed to decrease for all temperatures and storage times. Any correlation between the declining pH and development of unpleasant aftertastes will be further examined at the completion of storage trials.

Curried Sausages and Vegetables are not expected to achieve warranty based on these results. It is recommended that reformulation of this product be investigated to improve product quality and stability.

3.3 Vegetables

At the completion of 12 months at all temperatures minor decreases in water activity were observed for all vegetables. Decreases in pH were observed as the storage trial progressed and especially so with samples stored at elevated temperatures.

3.3.1 Carrots

This component has failed sensory evaluation at every time/temperature point, including initial, with decreases over time in quality of aroma, colour and flavour. The development of an unpleasant aftertaste and decreases in textural hardness were observed following 12 months storage.

Instrumental colour measurements recorded minor decreases in darkness (L*) at all temperatures. Red hues (a*), remained stable at 30 °C but decreased slightly at elevated temperatures. Substantial decreases in the yellow hues (b*) were observed, at 30 °C and 40 °C after 12 months storage. The decrease in yellow gives the impression of darkening as the colour shifts towards the blue end of the scale (Figure 9).

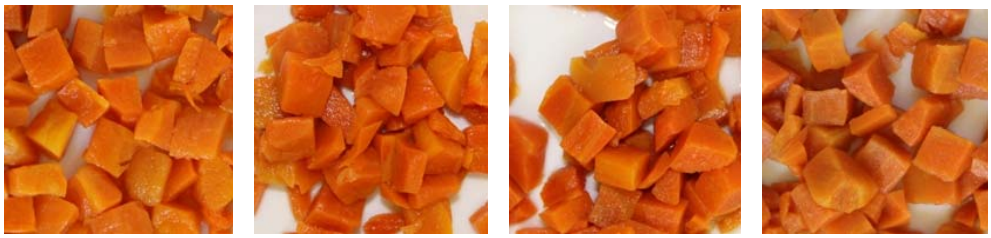

Figure 9. Images of Carrots after 12 months storage at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

3.3.2 Green Peas

There was no clear trend in the QDA data for characterising aroma, appearance data for colour, texture and characterising flavour. A high degree of sample-to-sample variation at each time/temperature storage point created noise that may have masked trends. This variation was evident in respect of colour and degree of splitting of the peas, which may suggest inconsistency in raw ingredients and/or processing. However, an unpleasant aftertaste developed over time at all storage temperatures, including 1 °C.

Images of samples of Green Peas are presented in Figure 10.

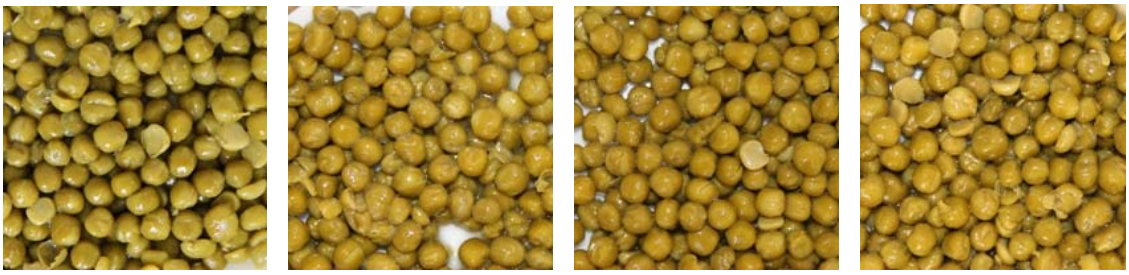

Figure 10. Images of Green Peas after 12 months storage at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

Instrument colour data was relatively stable with only minor changes observed: small decreases in a* and b* at 30 °C and 40 °C, whereas at 50 °C there was an increase in a* and a decrease in b*.

3.3.3 Sweet Corn

The QDA results record darkening and decreases in ratings for characterising aroma and flavour. In addition, an unpleasant aftertaste and greying of the kernels developed at elevated temperatures. Sensory textural attributes decreased over time for both hardness and chewiness, indicating a softening of the kernel. The degree of kernel splitting was variable from one sample to the next.

Figure 11 provides a visual representation of the changes over time.

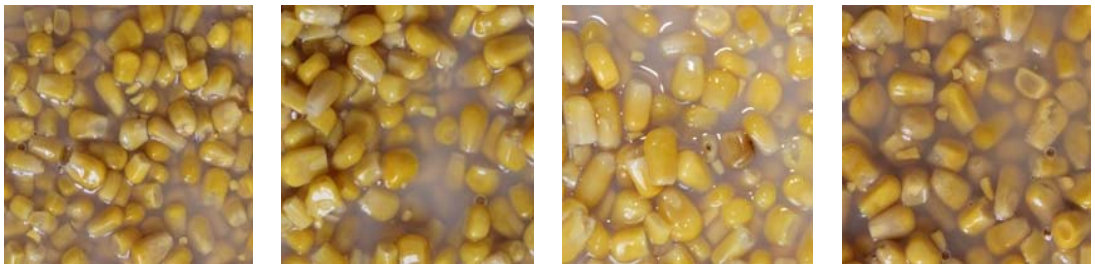

Figure 11. Images of Sweet Corn after 12 months storage at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

Instrumental colour observations support the QDA appearance and visual inspections with decreases in L*—or darkening—at 30 °C and above. Over time, the red hues (a*) increased as the yellow hues (b*) decreased, although the latter was variable from sample-to-sample.

3.3.4 Overall - Vegetables

Carrots, Green Peas and Sweet Corn have all been evaluated as either failing, or at risk of failing, warranty. It is recommended that action be taken to improve the initial acceptability of Carrots and Sweet Corn, and to stabilise flavour, colour and structure of all vegetables, thereby improving product quality and extending SL. The development of unpleasant aftertaste for all vegetable products and any correlation to decreasing pH will be further investigated at the conclusion of the storage trial.

3.4 Soup Mixes

At the completion of 12 months storage, water activity had increased for Cream of Chicken, Savoury and Tomato Soups.

Visual inspection revealed browning and caking of the soups, which increased with time and temperature, and was especially evident at elevated temperatures. This is evident in the images provided in Appendix D. The development of caking is subject to a critical hydration level being reached, at which the particle surface plasticises and merges with neighbouring particles. Caking is linked to water activity/content and glass transition temperature (Roudaut, 2007).

Headspace analysis was conducted to monitor oxygen and carbon dioxide levels during storage. As time and temperature increased, oxygen decreased and carbon dioxide increased. The lowest oxygen levels were 0.1% or less for all soups following storage at 50 °C for 8–12 weeks. Under the same conditions, the highest carbon dioxide levels were 34% for Savoury, 24%[7] for Tomato and 6% for Cream of Chicken. The reasons for the considerable departures from normal atmospheric levels[8] have not yet been determined.

[7] Mean of four results, one result excluded. For Savoury and Cream of Chicken the mean of five results was used in each case.
[8] Normal atmospheric levels: oxygen 21%, carbon dioxide 0.04%.

3.4.1 Cream of Chicken

Based on QDA results for the prepared product, there was darkening and decreases in characteristic aromas and flavours. Whilst clarity was retained, an unpleasant aftertaste developed. Overall acceptability also declined and the product is at risk of not achieving warranty.

Instrumental colour data supports QDA and visual observations of darkening due to non-enzymatic browning (NEB); decreases in L* with increasing time and temperature were recorded. Yellow hues (b*) remained stable over time at 30 °C and 40 °C, with minor decreases at 50 °C. Values for a* increased over time, with increasing temperature taking the colour into the red hues.

3.4.2 Savoury

At the completion of 12 months storage, darkening due to NEB was observed in the prepared sample, although clarity remained stable. Increased surface oiliness was also observed. Characteristic aromas and flavours decreased at elevated temperature but these changes were barely evident at 30 °C. The development of an unpleasant aftertaste was observed at all temperatures, although it was less pronounced at 1 °C. Instrumental colour results were consistent with the visual inspections and QDA appearance results.

Based on these results, this product will not achieve warranty.

3.4.3 Tomato

During storage, characteristic aromas and flavours decreased and an unpleasant aftertaste developed. Darkening of the prepared sample was indicative of NEB during storage. This was observed at all storage temperatures, with samples stored at elevated temperatures darkening to a greater degree and developing a burnt aroma.

These observations are supported by instrumental colour measurements showing decreases in L*, a* and b* with increases in time and temperature.

3.4.4 Soup Mixes - Overall

Based on the sensory data, the Soup Mixes have been evaluated as either failing (Tomato and Savoury), or at risk of failing (Cream of Chicken), warranty. It is recommended that approaches, such as alternative formulation and processing, be investigated to identify options to improve quality, to stabilise flavour, colour and structure, and to extend SL. Furthermore, improvements to packaging are recommended to reduce moisture migration and caking.

3.5 Fruit Spreads

Water activity decreased for the Marmalade, Strawberry Fruit Spread (FS) and Plum FS at all temperatures. °Brix and pH levels for these products remained stable over time and temperature. °Brix levels for the Marmalade, whilst stable, were lower than the specified value of ≥ 65 Bx° (FSC and DEF(AUST) 10423).

Phase separation was evident in all three components—more so in the case of Marmalade—at the completion of 12 months storage, regardless of storage temperature. A greater degree of separation and sample variation was observed as the temperature increased. Plots of the phase separation data are presented in Appendix E.

Phase separation is a direct result of break down in the gel structure allowing the aqueous phase to separate. The intermolecular forces associated with this structure are greatly influenced by pectin, pH, °Brix and water (Herbstreith & Fox KG). In addition, break down of the gel structure can be attributed to rupturing of the structure during filling of the tubes. This is dependant on the system used and the type of pectin in the product. Due to the naturally high levels of pectin found in citrus fruit, Marmalade is a product at higher risk.

3.5.1 Marmalade

This product is at risk of not achieving warranty, with darkening and bitterness developing during storage. Instrumental colour measurements were consistent with the sensory observations of darkening, with decreases for both L* and b*. The magnitude of decrease was greater in the yellow hues (b*) than darkening (L*), pushing the colour into the brown regions of the colour spectrum. Translucence was retained despite the browning. The changes in colour can be seen in Figure 12.

Whilst peel is an intrinsic part of Marmalade, it was observed that extrusion of the Marmalade was greatly hindered by the pieces of peel. The resistance to extrusion could be reduced by using a larger nozzle or finer pieces of peel.

Figure 12. Marmalade at 12 months, samples stored at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

3.5.2 Plum Fruit Spread

The sensory data for overall acceptability indicates that this component will achieve warranty. Darkening at elevated temperatures and small reductions in the characteristic plum flavour accompanied by increased sensory acidity, are not expected to change the predicted outcome.

This product is naturally dark, beginning at the lower level of the darkness scale (L*). At the completion of 12 months storage, decreases were observed for L* at 40°C whilst other temperatures remained stable. Decreases were observed for the red (a*) and yellow (b*) hues at 30 °C and 40 °C after 12 months storage, moving into the brown regions of the colour spectrum, indicating that NEB is occurring.

The development of browning in the 40 °C sample is clearly evident in Figure 13.

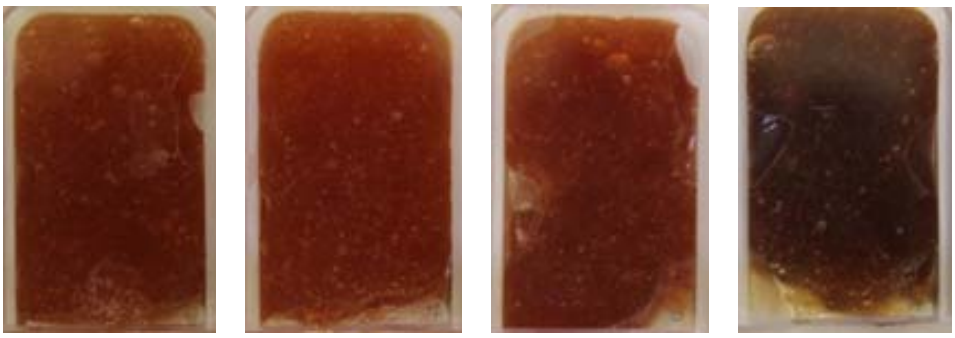

Figure 13. Plum Fruit Spread after 12 months storage. Samples stored at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

3.5.3 Strawberry Fruit Spread

Strawberry FS is expected to achieve warranty. The sweet aroma and flavour were relatively stable at 20°C and 30°C, but the sweet flavour was found to have decreased following 12 months storage at 40 °C. Strawberry aroma and flavour decreased while acid flavours increased with increasing time and temperature.

Based on the QDA visual appearance results, Strawberry FS darkened during storage, especially at higher temperatures. Although instrumental colour measurements did not detect darkening, they did record browning, which may have appeared to the human eye as darkening. The colour changes are evident in Figure 14.

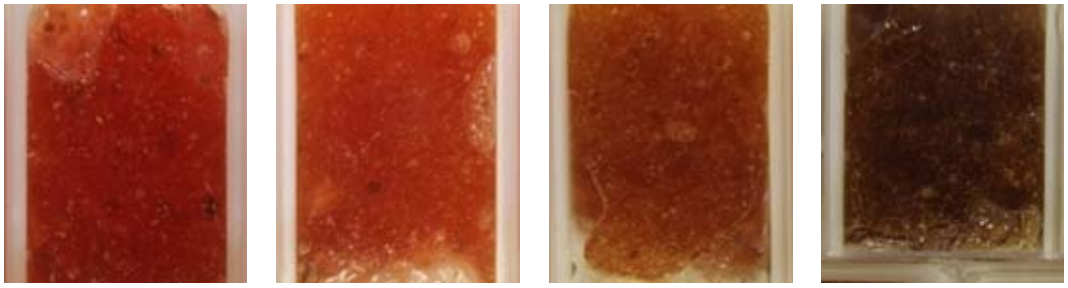

Figure 14. Strawberry Fruit Spread after 12 months storage. Samples stored at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

3.5.4 Fruit Spreads - Overall

Whilst the Fruit Spreads are expected to achieve warranty, based on sensory overall acceptability data, it is recommended that effort be directed towards reducing NEB and enhancing stability and SL. In addition, with Marmalade being at risk of not meeting warranty, it is recommended that consideration be given to reformulation to reduce the severity of phase separation.

3.6 Sports Drink Powders

Decreases in water activity were observed for the Lemon/Lime, Grape and Orange Sports Drink Powders at 30 °C and above. Whilst water activity remained below 0.5[9] throughout storage, it was within a range, which is conducive to development of NEB of 0.2 (Barbosa-Cánovas *et al*, 2007), which was evident for samples stored at elevated temperatures (Figure 15).

Visual packaging inspections indicated that the integrity of packages was maintained during storage.

A degree of caking/clumping was observed for all flavours. Caking/clumping for all flavours stored at 50 °C was over 90% caked, with samples not breaking into smaller clumps when shaken (Figure 15). Samples held at lower temperatures ranged from 40–80% caked, depending on flavour and storage temperature, and to various degrees broke into smaller clumps when shaken. The condition of the powders ranged from free flowing to liquefaction stage.

Figure 15. Sports Drink Powder, NEB & caking after 28 days storage at 50 ℃ for (left to right) Lemon/Lime, Grape and Orange flavours.

At the completion of 12 months storage, the solubility of all flavours at all temperatures was below 2% undissolved material. However, some samples took up to ten minutes to dissolve. No clear relationship was evident between the development of caking and changes to solubility at any one time/temperature point.

QDA identified that, for all flavours, acid flavour increased as sweetness decreased. This was more pronounced at elevated temperatures.

3.6.1 Sports Drink Powder – Lemon/Lime Flavour

QDA and hedonic overall acceptability determined minor changes to characteristic citrus aroma and flavour. Clarity was retained at all times and temperatures. Instrumental colour measurements, visual inspections and QDA all indicate that NEB occurred during storage.

[9] An acceptable level to restrict microbial growth.

3.6.2 Sports Drink Powder – Grape Flavour

Characteristic aroma, flavour, colour and clarity all decreased slightly with increasing time and temperature. Over time and with increasing temperature there was darkening of the product (instrumental colour and sensory appearance results).

3.6.3 Sports Drink Powder – Orange Flavour

Based on QDA, characteristic aroma, clarity and flavour remained stable whilst decreases were observed for appearance (colour), i.e. the colour shifted towards the darker end of the scale. Instrumental colour results also determined darkening with decreases to L* over time for all temperatures. No clear trends were established for a* and b*.

3.6.4 Sports Drink Powders – Overall

It is recommended that the product formulation be reviewed to improve quality, stability and SL including investigation of ingredients to increase resistance to NEB and caking. It is also recommended that alternative packaging be considered for improved barrier properties, which may further stabilise the product during storage, including reduction in caking.

3.7 Confectionery Products

3.7.1 Chocolate Candy

Due to a leak test failure rate of 59% during initial evaluation (De Diana and Coad, 2012), a condensed storage profile, omitting the 50 °C sampling points, was used.

Headspace analyses were conducted to monitor oxygen and carbon dioxide levels during storage. Although there were a few outlier data points within each set of five replicates, the trends were clear: reduced oxygen and elevated carbon dioxide at higher storage temperatures. The outlier data points appear, in most instances, to be due to failures in package integrity with normal atmospheric levels being maintained when the levels for other samples in the set changed significantly.

QDA identified decreases over time and with increasing temperature in the ratings for characteristic aromas and flavours, with subsequent development of aroma and flavour taints. The hardness and brittleness of the shell decreased while the graininess of the chocolate centre increased.

The hard candy shells had visible cracks in one or more samples for all storage profiles, with a decline in uniformity of colour at elevated temperatures. A dull, waxy/fat coating was observed at elevated temperatures (Figure 16). Control samples and samples stored at 30 °C retained the initial bright colouring of the candy shell. Water activity decreased substantially over time at 30 °C and 40 °C; potentially due to cracking of the shell and packaging with poor barrier properties.

Chocolate Candy for the 2010/11 CRP packing program was sourced from a different manufacturer to that used previously and since. Based on our experience with this type of product, our expectation is that the product sourced from the regular manufacturer will

outperform the product evaluated in this report. It is recommended that the 'regular' product be evaluated using the findings reported herein for guidance on potential problems.

Figure 16. Chocolate Candy following storage at 40 °C for 12 months. Note the white fat on the surface of the candy shell.

3.8 Hard Candy

No clear trend was apparent for water activity of Hard Candy variants stored at 40 °C and 50 °C. Water activity values initially decreased, then increased, and finally decreased again. It is surmised this is the result of water migration between regions until a_w values reach equilibrium during storage. This includes moisture exchange between product ingredients, packaging and the outside (Ergun et al, 2010).

Figure 17 presents the water activity for Hard Candy following storage for 12 months at the indicated temperatures. A 'drying out' of the product with increasing temperature is evident. It is also clear that the product absorbs moisture when stored at 1 °C in the relatively humid environment of the cool room. As noted in section 2.3, humidity was not controlled in the 20 °C, 30 °C and 40 °C storage cabinets, therefore the relative humidity in each cabinet is a function of ambient humidity and cabinet temperature. There is a drying out of the air as temperature rises and this is reflected in the water activity results (Figure 17). However, under normal storage conditions in Defence warehouses, the relative humidity at 30 °C would generally be higher and softening of the product would be expected.

The water activity results clearly demonstrate one of the problems that arise when packaging with poor barrier properties is used to protect a dry product; moisture transfers through the packaging into the product. This could be resolved by overwrapping with a suitable packaging material.

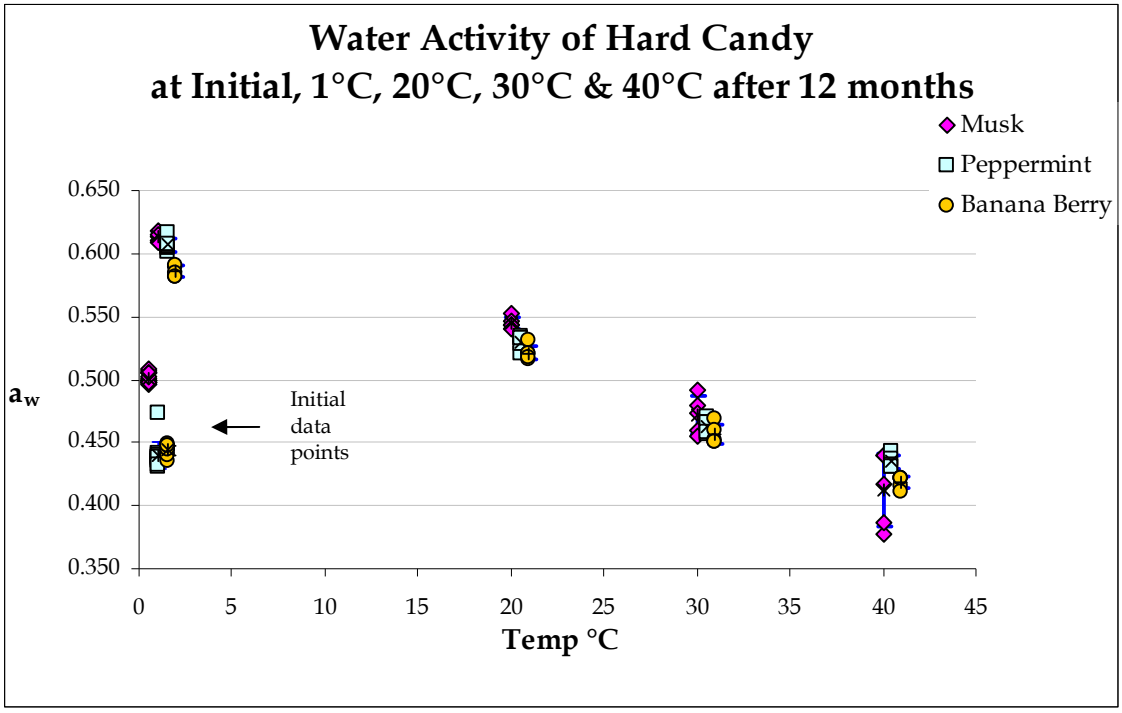

Figure 17. Water activity of Hard Candy following 12 months storage at 1 °C, 20 °C, 30 °C & 40 °C[10].

3.8.1 Musk Candy

Characteristic aroma, appearance and flavour attributes decreased slightly over time and temperature, with substantial decreases in brittleness observed at elevated temperatures. Visual observations noted a decrease in shininess at 30 °C, 40 °C and 50 °C, leaving samples with a dull and powdery appearance. An unpleasant packaging aroma was evident for all temperatures increasing over time.

There was no clear evidence of darkening, however minor increases in a* and decreases in b* were observed.

3.8.2 Extra Strong Peppermint (ESP) Candy

Based on QDA results, characterising aromas remained stable whilst decreases to textural brittleness and characterising flavours were observed. Appearance results indicated darkening and reduced surface gloss. Visual inspections noted yellowing of the product and development of unpleasant packaging odour over time for all temperatures. This is supported by instrumental colour measurements which detected increases in b* and minor increases in L* and a*.

3.8.3 Banana Berry Candy

The QDA results include decreases in brittleness and characterising flavours, whilst aromas remained stable. The appearance darkened and surface gloss reduced. During visual

[10] Temperatures have been offset by up to 1 °C to avoid overlap of data points.

inspections, substantial darkening of samples at 40°C and 50°C was noted, whilst samples at 30 °C and 40 °C were observed to develop a powdery coating. The packaging developed an unpleasant odour at all temperatures.

Instrumental colour data did not support visual and QDA data with only minor difference to L*, a* and b*, with a large degree of variation among samples. It is surmised that the speckled appearance of the product may have influenced the instrumental response.

3.8.4 Hard Candy – Overall

It is recommended that alternative products of this type be evaluated with a view to finding variants that are more likely to achieve warranty than the Musk and Banana Berry varieties. It is likely that significant improvements could be achieved through the use of packaging with improved barrier properties.

3.9 Sauces

Substantial losses of net weight were observed for Sweet Chilli Sauce and Tomato Ketchup. The losses appear to have been vapour losses with no apparent evidence of package leakage. Phase separation during storage was evident, although a substantial degree of sample variation was noted. Phase separation was less in samples stored at elevated temperature, probably due to the previously noted moisture loss.

Water activity and pH levels decreased, whilst °Brix levels increased for Sweet Chilli Sauce and Tomato Ketchup at all temperatures, being more substantial at 40 °C and more pronounced in Sweet Chilli Sauce.

3.9.1 Sweet Chilli Sauce

Based on QDA data decreases across the scale were observed for colour, characteristic chilli aroma and flavour ratings at all temperatures, indicative of darkening and a loss of volatiles. Burnt aromas and thickening of the sauce were also observed. Visual observations represented in Figure 18 and instrumental colour measurements support QDA data, with decreases to L* and substantial decreases in a* and b* at elevated temperatures.

Figure 18. Sweet Chilli Sauce after 12 months storage at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

3.9.2 Tomato Ketchup

QDA determined development of unpleasant aromas and flavours, furthermore increased fermentation aromas in conjunction with increased acidic flavour were observed. Darkening of the product was apparent from QDA, visual observations (Figure 19) and instrumental

colour results with decreases to L*, and substantial decreases to a* and b*, at elevated temperatures, and to a lesser degree at 30 °C.

Figure 18. Tomato Ketchup after 12 months storage at (left to right) 1 °C, 20 °C, 30 °C and 40 °C.

3.9.3 Sauces – Overall

It is recommended that the formulation of Sweet Chilli Sauce be reviewed to improve initial quality. It is also recommended the reasons for the decrease in net weight be investigated, including determination of packaging barrier properties.

4. Conclusions

The components evaluated in this storage trial are forecast to perform against warranty requirements as follows.

- Components that passed and are expected to meet warranty:

Chilli Con Carne	Lemon/Lime Sports Powder
Plum FS	ESP Candy
Strawberry FS	

- Components that are at risk of not achieving warranty:

Tuna in Springwater	Cream of Chicken Soup
Beef Teriyaki	Banana Berry Candy
Green Peas	Musk Candy
Marmalade	Tomato Ketchup
Grape Sports Powder	Sweet Chilli Sauce
Orange Sports Powder	

- Components that have either failed, or are likely to fail, to achieve warranty:

Braised Beef & Gravy	Sweet Corn
Chicken Curry	Chocolate Candy
Curried Sausages & Vegetables	Savoury Soup
Carrots	Tomato Soup

Where initial quality was marginal, a small subsequent decline would result in failure to achieve warranty. Components with higher initial quality can withstand a greater decline in quality without pushing to the point of failure.

5. Recommendations

1. Investigate components that have already failed warranty, or have been forecast as at risk of failing, with consideration given to reformulation, repackaging or replacement.

2. Beef Teriyaki, Beef & Gravy, Chicken Curry and Curried Sausages & Vegetables: investigate options to improve initial product acceptability quality and reduce the likelihood of failure during storage.

3. Carrots and Sweet Corn: take action to improve the initial acceptability.

4. All vegetables: take action to stabilise flavour, colour and structure, thereby improving product quality and extending SL.

5. Soup Mixes: approaches, such as alternative formulation and processing, should be investigated to identify options to improve quality, to stabilise flavour, colour and structure, and to extend SL. Furthermore, improvements to packaging are recommended to reduce moisture migration and caking.

6. Fruit Spreads: effort should be directed towards reducing NEB and enhancing stability and SL. In addition, with Marmalade being at risk of not meeting warranty, it is recommended that consideration be given to reformulation to reduce the severity of phase separation.

7. Sports Drinks: the formulation should be reviewed to improve quality, stability and SL including investigation of ingredients to increase resistance to NEB and caking. It is also recommended that alternative packaging be considered for improved barrier properties, which may further stabilise the product and reduce caking during storage.

8. Chocolate Candy: the 'regular' product should be evaluated using the findings reported herein for guidance on potential problems.

9. Hard Candy: alternative products of this type should be evaluated with a view to finding variants that are more likely to achieve warranty than the Musk and Banana Berry varieties. The feasibility of using packaging with improved barrier properties should be investigated as it is likely that significant improvements could be gained.

10. Sweet Chilli Sauce: the formulation should be reviewed to improve initial quality. It is also recommended that the reasons for the decrease in net weight be investigated, including determination of packaging barrier properties.

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Appendix A: Anticipated primary modes of deterioration

Products	Primary Modes of Deterioration									
	Biological		Chemical				Physical			
	Spoilage microorganisms	Pathogenic microorganisms	Oxidative rancidity	Loss and/or migration of volatiles (aroma and flavour)	Vitamin Loss (When fortified according to ADFFS)	Non-enzymatic browning	Moisture migration	Textural changes (harden, soften, brittleness, caking)	Staling	Syneresis
Tuna- Springwater	✓	✓	✓	✓	✓	✓	✓			
Braised Beef & Gravy	✓	✓	✓	✓	✓	✓	✓			
Chicken Curry	✓	✓	✓	✓	✓	✓	✓			
Curried Sausages & Vegetables	✓	✓	✓	✓	✓	✓	✓			
Chilli Con Carne	✓	✓	✓	✓	✓	✓	✓			
Beef Teriyaki	✓	✓	✓	✓	✓	✓	✓			
Carrots	✓	✓	✓	✓	✓	✓	✓			
Green Peas	✓	✓	✓	✓	✓	✓	✓			
Sweet Corn, whole kernels		✓	✓	✓	✓	✓	✓			
Cream of Chicken Soup	✓	✓	✓	✓	✓	✓	✓	✓		
Tomato Soup	✓		✓	✓	✓	✓	✓	✓		
Savoury Soup	✓	✓	✓	✓	✓	✓	✓	✓		
Lemon Lime Sports Beverage	✓	✓		✓	✓	✓	✓	✓	✓	
Grape Sports Beverage	✓	✓		✓	✓	✓	✓	✓	✓	
Orange Sports Beverage	✓	✓		✓	✓	✓	✓	✓	✓	
Plum Jam	✓			✓	✓	✓	✓			✓
Strawberry Jam	✓			✓	✓	✓	✓			✓
Marmalade	✓	✓		✓	✓	✓	✓			✓
Candy Chocolates	✓		✓	✓		✓	✓	✓	✓	
Musk Candy	✓			✓		✓	✓	✓		
ESP Candy	✓			✓		✓	✓	✓		
Banana Berry Candy	✓			✓		✓	✓	✓		
Sweet Chilli Sauce	✓			✓	✓	✓	✓	✓		✓
Tomato Ketchup	✓	✓		✓	✓	✓	✓	✓		✓

Appendix B: Sampling and testing regime for storage trial samples

Component name	*Quality Measurand*															
	Physical and visual[1]												**Organoleptic[2]**			
	Water activity (a_w)	Net weight[3]	pH	Colour change	Brix (Bx°)	Viscosity/Consistency	Texture Analysis	Changes in Solubility	Phase separation	Headspace O_2	Seal creep/ unrolling	Package defects	Appearance	Texture	Flavour	Overall acceptability
Tuna- Springwater	8	8		8							8	8	5	5	5	5
Braised Beef & Gravy	8	8	8	8							8	8	5	5	5	5
Chicken Curry	8	8	8	8							8	8	5	5	5	5
Curried Sausages & Vegetables	8	8	8	8							8	8	5	5	5	5
Chilli Con Carne	8	8	8	8							8	8	5	5	5	5
Beef Teriyaki	8	8	8	8							8	8	5	5	5	5
Carrots	8	8	8	8							8	8	5	5	5	5
Green Peas	8	8	8	8							8	8	5	5	5	5
Sweet Corn, whole kernels	8	8	8	8							8	8	5	5	5	5
Cream of Chicken Soup	8	8	8[4]	8				8		8		8	5	5	5	5
Tomato Soup	8	8	8[4]	8				8		8		8	5	5	5	5
Savoury Soup	8	8	8[4]	8				8		8		8	5	5	5	5
Lemon Lime Sports Beverage	8	8	8[4]	8				8		8		8	5	5	5	5
Grape Sports Beverage	8	8	8[4]	8				8		8		8	5	5	5	5
Orange Sports Beverage	8	8	8[4]	8				8		8		8	5	5	5	5
Plum Jam	8	8	8	8	8	8			8		8	8	5	5	5	5
Strawberry Jam	8	8	8	8	8	8			8		8	8	5	5	5	5
Marmalade	8	8	8	8	8	8			8		8	8	5	5	5	5
Candy Chocolates	8	8		8			8					8	5	5	5	5
Musk Candy	8	8		8			8					8	5	5	5	5
ESP Candy	8	8		8			8					8	5	5	5	5
Banana Berry Candy	8	8		8			8					8	5	5	5	5
Sweet Chilli Sauce	8	8	8	8	8	8			8			8	5	5	5	5
Tomato Ketchup	8	8	8	8	8	8			8			8	5	5	5	5

[1] Tests conducted at the individual packet level

[2] Evaluations conducted with 5 panellists on pooled samples of individual packet numbers as indicated

[3] Net weight measured throughout SL trial but only evaluated in the 24 month report

[4] Test conducted on reconstituted sample

Appendix C: Methods of analysis for shelf life assessment

Analysis	Product matrix	Method type[1]	Reference
Physical Testing and Visual Examinations			
Water activity (a_W)	All products	Dew Point Instrument	DSTO-Scottsdale in-house method based on AOAC (2007) 978.18C
Net weight	All products	Balance	DSTO-Scottsdale in-house method
pH	All intermediate and high moisture foods	pH meter	DSTO-Scottsdale in-house method based on AOAC (2007) 945.10
Colour change	All products	Light reflectance measurement using a colour meter	DEF(AUST) 10658:Part 2, Annex B, method B.3.
Total Soluble Solids (Brix)	Fruit Spread, Sauces	Refractometer method, measuring % sucrose	AOAC (2006) 932.12 or AOAC (2006) 932.14
Consistency	Sauces	A consistometer to measure flow rate (cm/30sec).	DEF(AUST) 10658:Part 2, Annex B, method B.9. & B.10.
Texture Analysis	Hard Candy	Texture Profile Analysis	DEF(AUST) 10658:Part 2, Annex B, method B.6.
Changes in solubility	All Soups and Sports Beverages	Measurement of insoluble matter	DEF(AUST) 10658:Part 2, Annex B, method B.11.
Headspace O_2	All Soups and Sports Beverages	Measurement of % oxygen in air sample removed from package and tested using an O_2 analyser	DEF(AUST) 10658:Part 3, Annex B, Method G.17.
Seal creep (including crimping unrolling)	Retort pouches and tubed products	Retort pouches: measurement by physical strength tested. Tubed products: visual inspection of seal creep.	DSTO-Scottsdale in-house methods
Packaging integrity/defect inspection	All products	Visual observation IAW DEF(AUST) and FSC requirements, including lacquer stripping, package swells, delamination	Cans DEF(AUST) 10658:Part 3, Annex B, method B.13. Tubes DEF(AUST) 10658:Part 3, Annex B, method C. 7. Flexibles DEF(AUST) 10658:Part 3, Annex G, method D.5.

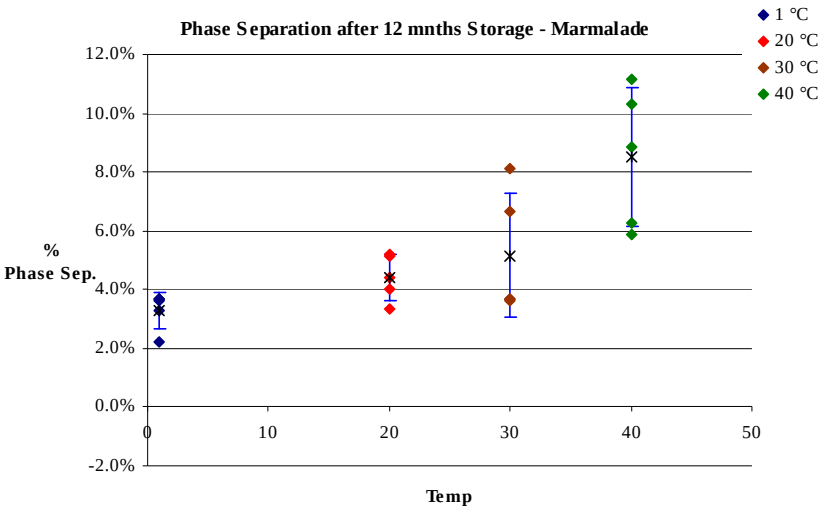
Analysis	Product matrix	Method type[1]	Reference
Organoleptic assessment			
Aroma, Appearance, Texture, Flavour and Overall acceptability	All products	Technical panel, QDA with overall acceptability 9-point Hedonic Rating	Chambers and Baker Wolf, 1996.

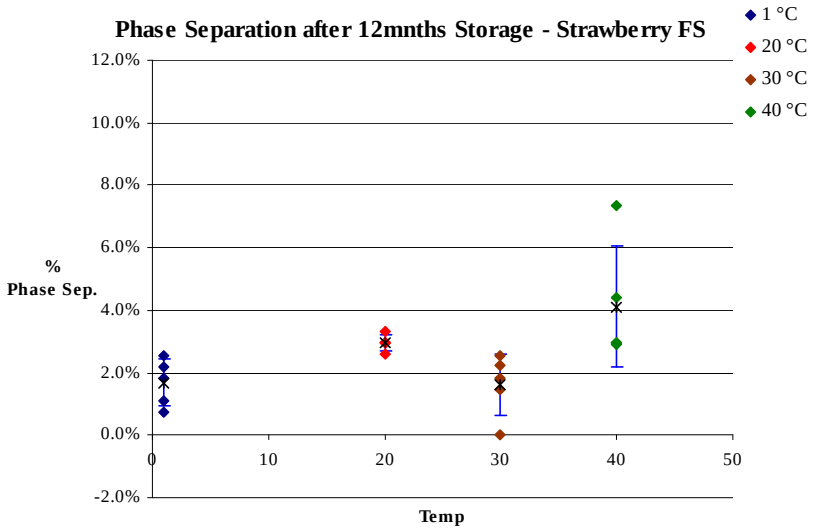
[1] Full details of methodology can be provided upon request

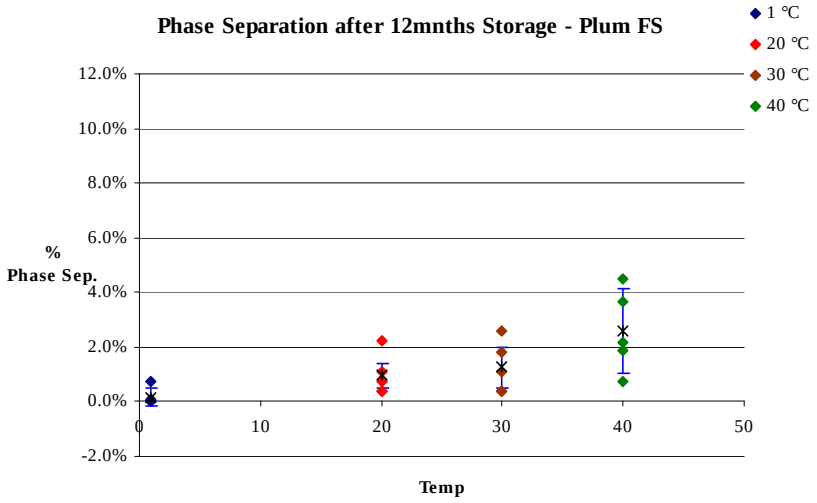
Appendix D: Caking and clumping of Soups

Profile	Cream of Chicken Soup	Tomato Soup	Savoury Soup
50 °C for 8 weeks			
1 °C for 12 months			
20 °C for 12 months			
30 °C for 12 months			
40 °C for 12 months			

Appendix E: Phase separation of Fruit Spreads







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19. ABSTRACT

DSTO provides science and technology support to DMO for the through-life management of combat ration pack components. This report details the performance of 24 components from the 2010/11 ration packing program following 12 months storage under controlled conditions. The results provide guidance as to the anticipated shelf life of each component and the ability of products to meet warranty requirements. The report concludes that 5 components are expected to meet the warranty requirements, 11 are at risk of failure and 8 have either already failed or are expected to fail.