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# Quality Evaluation of Dried Soup Mix Packaging

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## **ABSTRACT**

Soup mixes are dry products, making them vulnerable to moisture and oxygen during storage. Packaging must protect the product against rough handling and mechanical abuse, extremes of climatic and environmental conditions, and long periods of storage. Approval has been sought for the use of a paper/foil-based laminate to package soup mixes. To inform a decision on this request, the Defence Science and Technology Group has been asked to provide advice on compliance against Australian Defence Standard DEF(AUST) 10638 flexible packaging for combat ration packs, and to advise suitability of packaging for intended use.

The results demonstrated that the packaging material met water and oxygen barrier requirements, however did not possess mechanical strength sufficient to contain, protect and preserve the intended product throughout the warranty period. Recommendations for product improvement and further assessment, and improvement to DEF(AUST) documentation, have been provided.

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# Quality Evaluation of Dried Soup Mix Packaging

## Executive Summary

The Capability Acquisition and Sustainment Group (CASG) submitted samples of soup mix packaging (laminate and formed packets) to the Defence Science and Technology (DST) Group to assess its suitability for inclusion in combat ration packs (CRP).

The submitted packaging material was a paper/foil/polymer laminate. DST Group evaluated the function and performance of the proposed soup packaging against the requirements of Australian Defence Standard (DEF(AUST)) 10638, applying the methods specified in DEF(AUST) 10658; Part 3. The scope of DEF(AUST) 10638 assumes the use of polymer-based laminates and does not adequately consider the use of paper/foil-based laminates. Additionally, DEF(AUST) 10658, Part 3 does not specify test methods for paper/foil-based laminates.

The soup mix packaging was compliant for the following tests:

- oxygen transmission rate
- water vapour transmission rate
- compression testing
- package integrity (unfilled packets)
- ease-of-opening functionality.

The soup mix packaging was not compliant for:

- tensile strength
- puncture resistance
- tear strength
- package integrity (packets containing product).

Paper/foil-based laminates offer little in the way of mechanical strength and were not expected to perform as well as polymer-based laminates. The suitability for inclusion in CRP will only become clear if the scope of packaging evaluation includes exposure to environmental and climatic conditions typical of the Defence supply chain through to the use environment. Based on the evidence reported here, there is a moderate risk that the product will fail to meet the warranty requirement if the proposed packaging is used.

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It is recommended that CASG:

- investigates options for improving the mechanical strength of packaging to ensure it is tough enough to withstand physical damage whether initiated by the product/packaging interaction or from the environment alone
- assess package functionality and performance once exposed to the use environment (inclusive of rough handling and varied climatic/environmental conditions)
- investigate the reasons why two of the three product variants submitted failed package integrity testing
- review DEF(AUST) packaging standards and methodologies to include the use and evaluation of paper/foil-based laminates.

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## Glossary

95% CI	ninety-five percent confidence interval
CASG	Capability Acquisition and Sustainment Group
CRP	combat ration packs
DEF(AUST)	Australian Defence Standard
DST Group	Defence Science and Technology Group
FFSPs	formed, filled, sealed packages
FUPs	formed, unfilled packages
LDPE	linear low density polyethylene
OTR	oxygen transmission rate
RH	relative humidity
SD	standard deviation
WVTR	water vapour transmission rate

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## 1. Introduction

Soup mixes are low moisture (typically less than 5%), low water activity (0.2-0.4) products, making them vulnerable to the effects of moisture and oxygen during storage [1,2]. Packaging must protect the product against rough handling and mechanical abuse, extremes of climatic and environmental conditions, and throughout long periods of storage [3,4]. To deliver the functional requirements of containment, protection and preservation, a number of performance criteria have been identified [2], some of which are requirements placed on the laminate materials (including mechanical strength and high barrier properties) and others on the formed, sealed packages.

A potential new supplier of soup mixes has submitted samples to Capability Acquisition and Sustainment Group (CASG) for their consideration. Subsequently, CASG has requested Defence Science and Technology (DST) Group evaluate the product and its packaging against Australian Defence Standard (DEF(AUST)) 10550 Instant Cereal Based Preparations [1], and its supporting standards [2-3].

This report details the findings of a quality and compliance evaluation of the proposed packaging against DEF(AUST) 10638 Flexible Packaging for CRP Foodstuffs [2].

## 2. Materials and Methods

### 2.1 Packaging samples

Packaging samples of three forms were submitted:

- laminate sample extracted from a rewind roll (260 mm wide, 15 m in length)
- formed, unfilled packages (FUPs) ( $n = 50$ )
- formed, filled, sealed packages (FFSPs) containing soup mix ( $n = 90-100$  of three flavour variants).

The packaging specification provided described the laminate structure as 45 gsm clay coat paper laminated to 16 gsm low density polyethylene (LDPE)/6.35  $\mu\text{m}$  aluminium foil/25 gsm surlyn [5].

### 2.2 Packaging tests and examinations

Inspection and testing was, in large, conducted in accordance with the methodologies specified in DEF(AUST) 10658, Part 3 [6]. Initial visual inspection was conducted on all samples to identify manufacturing and forming defects. All FUPs and FFSPs were tested

for package integrity (leak testing) under vacuum<sup>1</sup>. Seal strength and compression testing were assessed using FUPs.

Abrasion resistance (a future requirement) and delamination were not evaluated on the laminates supplied. DST Group is in the process of establishing the capability to test these properties.

Resilience and integrity testing (other than under static load) of FUPs and FFSPs were not performed as they are future requirements. Migration of odours, flavours and taints, package permeability and environmental testing were not performed either. Again, DST Group is in the process of establishing the capability to test these properties.

### 2.3 Data analysis

Where appropriate, descriptive statistics were generated as measures of central tendency and variability for all numeric data sets captured. Means, maximum, minimum, standard deviations (SD) and 95% confidence intervals (95% CI) were calculated. Standard deviations were calculated using the unbiased or 'n-1' method.

To test the null hypothesis that the population mean was equal to the specified value, one-sample T-tests were evaluated at the 5% significance level. If the test result was found to be significantly higher or lower than the specified maximum or minimum respectively, the result was designated as a "Fail". Otherwise, the result was designated as a "Pass".

## 3. Results and Discussion

### 3.1 Laminate properties

The laminate presented to DST Group was assembled using paper, foil and polymeric materials. DEF(AUST) 10658, Part 3 [6] identifies standard test methodology for evaluating performance of polymer-based laminate materials (in line with the requirements of DEF(AUST) 10638 [2]). Neither methodology nor performance criteria are ideal, and not particularly relevant, when assessing performance of a paper/foil/polymer laminate. No standard test methods are known for such laminate structures.

The performance criteria set in DEF(AUST) 10638 [2] are those expected when a polymer-based (flexible) laminate material is used to package product. A paper-based laminate, by its nature, will exhibit strength properties quite different to a polymer-based material. Paper offers significantly greater stiffness properties than do polymers, however mechanical strength properties (such as tear, tensile and puncture resistance) are limited.

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<sup>1</sup> This is a non-destructive test.

Given that the properties, functionalities and performance expectations of paper are quite different to polymer, the standard test methods used to evaluate polymer-based materials (those specified in DEF(AUST) 10658, Part 3 [6]) are different to those typically used by the paper industry. Paper-based laminates are unlikely to meet the mechanical strength performance standards set for flexible CRP packaging.

### 3.1.1 Tensile strength

A product's tensile strength is its resistance to rupture under a slowly applied force. Tensile testing provides information including the force required to deform the material (tensile modulus of elasticity), the tensile energy to break (and at break), the maximum tensile stress the material can sustain (ultimate tensile strength), and the stretch factor (percent elongation at break).

The proposed laminate failed to meet the DEF(AUST) requirement for tensile strength (100 N/cm – 250 N for a sample that is 2.5 cm wide, as tested). Laboratory measurements ( $n = 10$ ) found the maximum load to be significantly ( $p < 0.001$ ) less at 98 N (95% CI, 75-121 N) when sampled in the machine direction<sup>2</sup>. When sampled in the transverse (cross) direction, laboratory measurements ( $n = 10$ ) also found the maximum load to be significantly ( $p < 0.001$ ) less at 84 N (95% CI, 70-98 N). The load at break was highly variable (4-155 N) and dependant on the mode of failure, be it a clean break, incomplete break and/or delamination during extension.

### 3.1.2 Puncture resistance

The proposed laminate failed to meet the DEF(AUST) requirement for puncture resistance (150 N). Laboratory measurements ( $n = 10$ ) found the load at rupture to be significantly ( $p < 0.001$ ) less at 7.0 N (95% CI, 6.7-7.3 N) and the maximum load to be significantly ( $p < 0.001$ ) less at 10.1 N (95% CI, 9.3-10.9 N).

A material's response to puncture will vary with numerous factors, such as laminate thickness, elastic modulus, rate of penetration, temperature, and shape and type of instigator. In a military environment, likely instigators of puncture will be far reaching and every bit as likely to be introduced by objects within a soldier's combat ensemble as they are from the environment and/or other CRP components in close proximity. There is little benefit in ensuring a product is stored safely for a long period of time only to be spoiled by package puncture and product contamination when consumption is imminent.

CASG should ensure that packaging materials are tough enough to withstand enduring and acute causes of product deterioration. Puncturing of a material can result from sharp/abrasive products contained within the package (rupturing the material) or from abrasive/sharp materials (impacting the outer surface of the package). These actions may result in gross failures to the material or microscopic 'pinholing', both of which allow transfer of water, gases, flavours, microbes and contaminants, thereby instigating spoilage.

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<sup>2</sup> Test samples are removed from the laminate roll in either a parallel or perpendicular direction to the roll run (i.e. machine direction or transverse direction respectively).

Puncture resistance is a measure of the energy absorbing ability of a laminate in resisting protrusion. Paper and aluminium foil, as key components to this laminate material, offer little protection against acute causes of puncture. The mechanical strength properties of this laminate are dependant on the strength properties of the LDPE and the sealant layer (surlyn).

To understand the protective performance of a paper/foil-based laminate against acute hazards, packaged product needs to be assessed in a use environment involving rough handling.

### 3.1.3 Tear Strength

The proposed laminate failed to meet the DEF(AUST) requirement for tear strength (30 N). Laboratory measurements ( $n = 10$ ) found the maximum load to be significantly ( $p < 0.001$ ) less at 1.3 N (95% CI, 1.2-1.4 N) when sampled in machine direction. Transverse direction samples also significantly ( $p < 0.001$ ) failed, at 1.9 N (95% CI, 1.6-2.2 N). These results are comparable with the properties of the polymers (LDPE and surlyn) used in the laminate structure. Tear strength is a function of a product's ultimate resistance to tear. Test results reported herein are for the propagating tear strength (using an initiated sample). Initiating tear strength was not evaluated as the sachets had a tear notch for easy-opening (so initiation had been effected).

Soup mixes are likely to have sharp edged and granular ingredients, and if abraded or compressed during handling, distribution and storage may puncture the laminate. DST Group recommends CASG investigate the risk of tear to soup packets as they move through the supply chain, including in field use environments, to identify the serviceability of a paper/foil/polymeric laminate to contain and protect content from its environment.

### 3.1.4 Water vapour transmission rate

The packaging specification reports a water vapour transmission rate (WVTR) of  $< 0.1 \text{ g/m}^2.24 \text{ h}$  when tested at  $37.8 \text{ }^\circ\text{C}/90\% \text{ RH}$  [5]. The proposed laminate was found compliant with the DEF(AUST) requirement ( $0.03 \text{ g/m}^2.24 \text{ h}$ ; testing at  $30 \text{ }^\circ\text{C}$  and  $50\% \text{ RH}$ ). Laboratory measurements ( $n = 6$ ) found the WVTR to be  $< 0.01 \text{ g/m}^2.24 \text{ h}$  not only when tested under Defence specified conditions but also when tested under other internationally recognised test conditions ( $37.8 \text{ }^\circ\text{C}/90\% \text{ RH}$  and  $37.8 \text{ }^\circ\text{C}/100\% \text{ RH}$ ).

The integrity of a paper/foil/polymeric laminate is likely to be challenged during the forming, filling and sealing process. While the laminate has passed the WVTR, further evaluation of the water permeability of FUPs and/or FFSPs is required to understand and evaluate performance of the laminate material (in a formed package) once exposed to typical packaging processes. DST Group recommends further testing of the WVTR subsequent to treating/conditioning laminate under standardised flex conditions. This exposure and subsequent WVTR testing can inform the flex durability of laminates and provide guidance on the water permeability of packages [7].

### 3.1.5 Oxygen transmission rate

The packaging specification reports an oxygen transmission rate (OTR) of  $<0.5$  cc/m<sup>2</sup>.24 h when tested at 23 °C/0% RH [5]. The proposed laminate was found to be compliant with the DEF (AUST) requirement (0.03 cc/m<sup>2</sup>.24 h.atm at 30 °C and 50% RH). Laboratory measurements ( $n = 6$ ) found the OTR to be  $<0.01$  cc/m<sup>2</sup>.24 h.atm not only when tested under Defence specified conditions, but also when tested under the internationally recognised test conditions (23 °C/0% RH).

As per section 3.1.4, further test and evaluation of this laminate is required to confirm the performance when formed into packages.

## 3.2 Formed, unfilled packages

### 3.2.1 Package integrity

The FUPs of soup passed the DEF(AUST) requirement for package integrity. Of the 58 samples tested, 1 failed (1 fine leak) – a defect rate of  $<2\%$ . DEF(AUST) 10661 [8] permits a failure rate of 1 in 50 for critical defects (course or fine leaks) in non-destructive testing.

### 3.2.2 Seal strength

Seal strength is listed as a future requirement within DEF(AUST) 10638. Seal strength plays a pivotal role in maintaining packaging integrity and for this reason it has been evaluated and reported. Samples were extracted from left, centre and right side of the top seal and from the top, middle and bottom of the side seals (with sampling from both the left and the right side seals being represented in the data captured ( $n = 90$ )). The average seal strength (maximum load) was found to be  $2.4 \pm 0.3^3$  kg.force. On average the top seal performed marginally better than the side seals. The most common mode of failure during testing was a cohesive peel of the sealant layer. Occasionally, delamination was observed during testing.

### 3.2.3 Compression testing

The FUPs of soup passed the DEF(AUST) requirement for package integrity. Laboratory measurements ( $n = 20$ ) found all FUPs to retain package integrity when exposed to a 120 kg downward force for 30 seconds. Subsequent to testing there was little, if any, evidence of seal creep.

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<sup>3</sup> Results reported as  $\pm$  one standard deviation unless otherwise indicated.

### 3.3 Formed, filled, sealed packages

#### 3.3.1 Package integrity

Of the 291 samples tested, 131 failed (83 with coarse leaks and 48 with fine leaks) – a defect rate of 45%. DEF(AUST) 10661 [8] permits a failure rate of 1 in 50 for critical defects (course or fine leaks) in non-destructive testing. Table 1 provides the full data summary for each of the three product variants submitted. The FFSPs for two of the three flavour variants failed to meet the DEF(AUST) requirement for package integrity. Only the golden pumpkin soup variant passed package integrity testing. This product variant is likely to have been produced using a different packing machine or the same machine with different settings, as the top seal was found to be substantially wider. This has likely produced a superior package. It is also possible that the inclusion of croutons in the latter two variants increased the likelihood of damage (micro-failure) to the packaging material and may be the reason why a narrower seal width was affected.

Table 1 Package integrity (leak testing) results for soup mix packages

Product	Product Code	Total tested	Fine Fail	Course Fail	Failure rate
Golden Pumpkin Soup	S85892	90	2	0	2%
Cream of Mushroom Soup	S85895	101	13	43	55%
Cream of Chicken Soup	S85891	100	33	40	73%

Packages that have lost integrity are neither air nor water tight. As soup mixes are sensitive to ingress of oxygen and water, there is a substantive risk of product failure short of the warranty period. DST Group recommends that CASG investigate the reasons why two of the three product variants failed package integrity testing.

#### 3.3.2 Package dimensions, seal width and ease-of-opening functionality

Packages complied with the DEF(AUST) requirement for minimum seal width ( $\geq 3$  mm). Laboratory measurements ( $n = 10$  for each of the three variants) found the left and right seals to be significantly ( $p < 0.001$ ) greater at  $12.0 \pm 0.6$  mm and  $8.4 \pm 0.3$  respectively. The top seal was also significantly ( $p < 0.001$ ) greater with a minimum width of  $14.9 \pm 0.4$  mm. The pumpkin seal width was approximately twice as wide as the other soup mixes – those that contained croutons.

Packets did not present with an ease-of-opening functionality. Seal edges were straight cut (rather than a serrated edge) and no tear notch was identified. Given packets were manufactured using a paper/foil-based laminate, they were inherently easy to tear open even without a deliberate action to insert such a function.

There is no formal DEF(AUST) requirements for package dimensions. There is however benefit in minimising the surface area of packages to optimise barrier properties and

containment potential. For this reason, gross package dimensions were evaluated ( $n = 20$ ) and found to be:

- length,  $140.5 \pm 0.0$  mm
- width,  $120.8 \pm 0.4$  mm.

CASG could consider reducing the packaging size. Current packages have a substantial headspace and reducing such could contribute to reducing the overall volume of CRP and improve shelf life (by reducing the surface area of the packages). There may also be cost benefits by reducing the packaging cost.

## 4. Conclusions

The scope of DEF(AUST) 10638 does not adequately consider the use of paper/foil-based laminates. This standard assumes the use of polymer-based laminates. Additionally, DEF(AUST) 10658, Part 3 does not specify test methods for paper/foil-based laminates.

Paper/foil-based laminates are not expected to perform as well as polymer-based laminates.

The laminate submitted was found to be compliant with OTR and WVTR requirements. However, it was not compliant with mechanical properties requirements (tensile strength, puncture resistance and tear strength).

The FUPs were compliant with packaging integrity and compression strength requirements. Seal strength data was captured in support of this assessment.

Only one of the three flavour variants (pumpkin soup mix FSPs) was compliant with packaging integrity. This product variant was likely produced using a different packing machine or the same machine with different settings, as the top seal was found to be substantially wider. This has likely produced a superior package. It is also possible that the inclusion of croutons in the other two variants increased the likelihood of damage (micro-failure) to the packaging material. Packages that have lost integrity potentially expose product to levels of moisture and oxygen that places warranty compliance at risk.

Packets were easy-to-open.



## 5. Recommendations

DST Group recommends that CASG:

- investigates options for improving the mechanical strength of packaging to ensure it is tough enough to withstand physical damage, whether initiated by the product/packaging interaction or from the environment alone
- assess package functionality and performance once exposed to the use environment (inclusive of rough handling and varied climatic/environmental conditions)
- investigate the reasons why two of the three product variants submitted failed package integrity testing
- review DEF(AUST) packaging standards and methodologies to include the use and evaluation of paper/foil-based laminates.



## 6. References

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