PROPOSED METHOD FOR ASSESSING PACKAGING OPTIONS FOR FOOD AID PRODUCTS: THE CASE OF FORTIFIED VEGETABLE OIL

A Report from the Food Aid Quality Review

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ACRONYMS

CRS	Catholic Relief Services
FAQR	Food Aid Quality Review
FFP	Food for Peace
FY	Fiscal Year
G	Gram
KG	Kilogram
L	Liter
MT	Metric Ton
PET	Polyethylene Terephthalate
USAID	United States Agency for International Development
UV	Ultraviolet
VO	Vegetable Oil

Please note: Monetary amounts cited in this report are in U.S. dollars

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I. EXECUTIVE SUMMARY

The United States Agency for International Development (USAID) is the largest donor of food assistance in the world. In fiscal year 2017 (FY 2017), USAID's Office of Food for Peace (FFP) donated more than 1.4 million metric tons (MT) of food aid products which were distributed in more than 30 countries (1). U.S. food aid products play a key role in efforts to fight malnutrition among the most vulnerable populations, but stakeholders along the food aid supply chain have long been reporting challenges related to packaging which lead to losses and system inefficiencies. As part of efforts underway to improve food aid packaging, a packaging review was included in the 2016 scope of work for the Food Aid Quality Review (FAQR) project.

As an input to USAID's ongoing food aid packaging dialogue with stakeholders on appropriate ways to move forward, this report proposes a comprehensive method to compare packaging options based on their cost-effectiveness. The approach includes an assessment of costs, performance and functionality, and proposes a grading system to identify the most cost-effective option: the packaging technology that best optimizes these three criteria.

The approach was tested on the case of Fortified Vegetable Oil (VO). VO is among the main value-added food aid products donated by USAID for both development and emergency programs. In FY 2017, USAID procured 84,092 MT of VO for Title II programs, mostly packaged in four-liter tins (1). However, feedback from field-based partners indicates that this packaging does not provide the performance and functionality needed to ensure that VO reaches food aid recipients efficiently (2). It is estimated that 1 to 2 percent of procured VO are lost, or about $ 1.5 million (3), while up to 10 percent need to be reconditioned (transferred to new packaging to prevent losses due to damage to the original packaging), which could cost an additional $ 2.5 million[1,2] (U.S. dollars).

Six different types of packaging were evaluated: three different cylindrical tin cans with a plug similar to the closure currently being used, one cylindrical tin can with a plain top without a plug, one rectangular (F-style) tin can with a pullout spout and one plastic (polyethylene terephthalate or PET) bottle.

A cost comparison was conducted to assess the impact that packaging would have on operations, packaging, ocean freight, inland transport and storage costs. The total cost of the six packaging options was compared to the estimated average total cost of VO in its current packaging. The performance of the six different packaging options was then evaluated via laboratory testing and functionality was assessed based on handleability, distribution practicality, usage practicality, food safety, packaging reusability and packaging waste generation.

The cost, performance and functionality of each packaging option were graded and a cost-effectiveness score was generated. The method proved effective at discriminating packaging

[1] "Damages" refer to foods or packaging whose quality was altered but the food could be salvaged (i.e. a leaking can of oil, but some oil could still be used and/or reconditioned in another bottle). "Losses" are defined as packaging and/or foods that were damaged and could not be recovered (i.e. physical loss due to leaking can, spoilage, etc.).

[2] The cost of reconditioning is discussed in *Section IV.d.1*.

options based on their cost-effectiveness and provides a framework to decisionmakers to guarantee that a comprehensive approach is taken when packaging options are evaluated.

Moving forward, additional packaging options should be tested following the same method. **We propose the following approach and next steps to continue the ongoing efforts for food aid packaging revision:**

1. Food aid and packaging suppliers must be regularly informed of challenges faced in the field and provided with specific feedback regarding the causes of damage and losses.
2. Current and new food aid and packaging suppliers should be encouraged to propose packaging options which address current challenges.
3. The proposed packaging options should be assessed following the method presented in this report to ensure that a comprehensive assessment is conducted and that the most cost-effective options are identified.
4. The most cost-effective options should be trialed in the field to confirm their cost-effectiveness before being rolled out.

II. INTRODUCTION

II.a. Context and Objectives

The U.S. food aid supply chain is long and challenging. The foods used as food aid are produced and packed in the U.S., and transported from the supplier's facility to a U.S. port by rail or truck. They are then shipped to recipient countries via ocean-going carriers, a journey which can last up to two months. At the recipient port, these foods are typically either unloaded by hand and then loaded by hand onto trucks for transport to the warehouses or the shipping containers are transferred onto trucks directly, thus avoiding a handling step.

After delivery to the recipient location, the foods are transferred through one or more warehouses in-country prior to distribution. Some roads, particularly during the rainy season, are in very poor conditions and the trucks available locally do not always provide the level of protection and security typically required in the U.S. for food transport. The foods therefore undergo a great deal of shocks and vibrations which can have negative impact on packaging. Environmental conditions (including in warehouses) are unforgiving and the food aid products are commonly exposed to extreme heat, humidity and sunlight which can impact packaging integrity.

The nature of this food aid supply chain therefore involves a high risk of damage or losses between production and consumption of the foods. Packaging plays a key role in preserving their integrity until they are ready to be consumed by the recipients. Feedback from implementing partners and observers in the field have indicated issues related to packaging performance (2), which led to ongoing efforts from USAID/FFP and food aid suppliers to update packaging and address these challenges. However, because of the length of the supply chain and the many stakeholders involved, there is a lack of insight on operations once the foods arrive in-country. Therefore, it is difficult to assess the full impact of the packaging solutions proposed on all levels of the supply chain. To assist USAID/FFP in evaluating the suitability of packaging options for food aid products, the Food Aid Quality Review Project (FAQR[3]) drafted a comprehensive method which lays out the main factors to consider when revising food aid packaging.

This method evaluates packaging based on cost, performance and functionality to ensure that the most cost-effective packaging option–the one which best optimizes these three components–can be identified.

Cost is critical. Foods are donated by USAID and therefore an increase in costs would result in a smaller volume procured and fewer food aid recipients reached. Changing packaging will not only have an impact on packaging and food procurement costs but will also affect transport and storage costs because of changes in space occupation and handleability. Costs therefore need to be assessed at all levels of the supply chain. In addition, performance must be optimal. The supply chain is long and difficult, and an effective packaging system is essential to ensure that foods reach

[3] The Food Aid Quality Review (FAQR) project, funded by the United States Agency for International Development's Office of Food for Peace (USAID/FFP) under contract AID-OAA-C-16-00020, provides USAID and its partners with evidence-based, actionable recommendations on ways to improve nutrition among vulnerable people for whom the direct distribution of food aid can make a significant impact.

the recipients and maintain their integrity until consumption. Finally, functionality, or the practicality of packaging, should also be considered. Although optimizing shipping and storage is important from the financial perspective, functionality plays a key role in how the foods are used and handled, particularly at the end of the supply chain.

This report lays out a method to assess the suitability of packaging solutions for use with food aid products and identify the most cost-effective option. It includes a cost comparison, performance evaluation, and functionality assessment, and discusses how to measure cost-effectiveness based on these three components. The approach is applied here to fortified vegetable oil but can be used for any food aid product

II.b. The Case of Vegetable Oil

Vegetable oil (VO) has been distributed in food aid programs since 1955. Micronutrient fortification of procured oil started in 1998 with vitamin A; vitamin D was introduced in 2012. In FY 2017, USAID procured 84,092 MT of VO for Title II programs (1). Four packaging types are currently approved for packing VO for use in international food aid programs: 208-L drums, 20-L pails, 4-L plastic bottles and 4-L cylindrical-style cans (4). The cans and bottles are packed in corrugated boxes containing six cans or bottles per box. VO in 4-L cans makes up the largest portion of VO procured by USAID FFP in FY 2017. Over time, few changes have been made to the design of the packaging of VO, but some issues remain and USAID FFP often receives reports of losses and damages from implementing partners.

II.b.1. Packaging Damage and Breakage

Picture 1: Stacks of VO in Burkina Faso

Photo credit: FAQR, Burkina Faso

The long food aid supply chain creates ample opportunities for damage, degradation and losses from the time the foods ship from the U.S. to distribution to food aid recipients. The environmental conditions (including in warehouses) can cause the boxes to become humid and lose their strength. Rust can develop on the cans, particularly when they are stored too close to the ground, which can lead to the formation of holes. It is not uncommon to have stacks of cartons which are 18 to 20 layers high. Warehouse workers commonly climb on the boxes to reach the top of the stacks (Picture 1).

Cases of VO are usually not palletized and must be handled individually manually, which can result in more damage. When oil leaks, even low amounts of oil can spread on other boxes which become difficult to handle (Picture 2). Moreover, warehouse staff do not have time to open each box to identify which cans are leaking and

Picture 2: Stained boxes of VO in Ethiopia

Photo credit: Save the Children, Ethiopia

Picture 3: Dented cans in Ethiopia

Photo credit: Save the Children, Ethiopia

remove them. Even though the overall volume lost may not be very high, these challenges should be addressed to improve efficiency.

Interviews with stakeholders indicate that the area around the plugs is a weak spot where leakages originate. Cans could endure significant deformation throughout transport (Picture 3). Plugs are only pushed in after filling and the seal is therefore not fully airtight. When the top of the can is dented, the joint between the can opening and the plug is also deformed and leakage can occur. The pressure which builds up inside the can because of the movement of the oil during transport may also cause the plugs to be pushed up or oil to leak. In addition, one commonly-used stacking method in warehouses is "staircase stacking," which allows workers to step on the boxes to reach the top of the stack (5). This may result in the plugs getting pushed inside the cans, thus leading to leakage.

Comments also suggest that some leakage might be due to stacking at excessive heights during storage. Although it is recommended that stacks be no higher than 10 cartons (6), it is not uncommon to find stacks as high as 18 or 20 layers. This may cause bulging and ultimately leakage of the cans. While attempts are made to better educate warehouse workers on proper handling and storage of the food aid products, space in warehouses is limited and the conditions in the field do not always allow them to follow good warehouse practices. This should be considered in the design of the cans, which must have good compression strength.

On occasion, plastic containers are also used for the packing of oil. Implementing partners consistently indicate that the 4-L plastic jugs are not optimal because they cannot withstand long periods of stacking and require warehouse staff to recondition them in new bottles. This becomes an environmental concern if they are too damaged and cannot be repurposed (7).

II.b.2. Nutrient Degradation and Food Safety

The high unsaturated fatty acids content of most vegetable oils makes them susceptible to oxidation which rapidly degrades the sensory qualities of the oil (8). Heat, Ultraviolet (UV) and visible light accelerate the formation of free radicals which then trigger oxidation (9). VO also contains vitamin A and vitamin D which are two vitamins sensitive to light and oxygen (10). Metal containers provide effective barriers to both oxygen and light, but when oil is reconditioned or repackaged in plastic containers (which are often transparent) at the end of the supply chain, vitamin levels most likely drop significantly and the content at the time of consumption may be a lot lower than intended. Also, when the integrity of the cans or plugs are altered because of damage throughout the supply chain, oxygen can enter the containers and promote oxidation. It is estimated that VO fortification costs $6.09 per MT (11), or more than $500,000 per year. Protecting micronutrient content could have significant cost-effectiveness implications.

The use of 4-L containers may also introduce risks during distribution. Indeed, food aid recipients rarely receive four liters of VO at one time. Because of this, VO must be repackaged at the distribution site. Often recipients bring their own containers to receive VO, which may introduce food safety issues and reduces the quality of the product because recipients' containers are not always clean and do not close hermetically, etc.[4]

II.b.3. Space and Volume

Because the 4-L size is not a standard packaging size in the U.S., the cans are made exclusively for USAID. This explains why there is only one can supplier and why some oil vendors chose to invest in their own can-making line. Because of their different dimensions, the two types of cans cannot be stacked together. This increases space occupation in warehouses and results in logistical complications.

In addition, space occupation can significantly affect storage and shipping costs. The round shape of the existing cans results in more than 20 percent of empty space in the cases containing six cans of VO. The shipments reach the volume capacity of the 20-foot containers before they reach the weight capacity. This leads to increased shipping costs and high space occupation in warehouses. VO is also sometimes packaged in 4-L plastic jugs which are less resistant, cannot be stacked as high as the cans and therefore take up more space in the warehouses.

II.b.4. Functionality

Implementing partners have reported that the current packaging makes distribution inefficient by increasing the risk of loss and slowing operations (12). Since the plugs which close the cans are at the center of the lid, pouring from the plugs is messy[5]. VO also stays trapped in the cans, leading to losses. In addition, the holes are small and pouring oil through them is slow due to restricted air flow. Food aid recipients and implementing partners typically need to poke additional holes in the cans using tools to distribute the oil (Picture 4).

Picture 4: Cans opened by poking holes in the lids and discarded

[4] VO, however, is typically consumed cooked which significantly reduces the food safety concerns. In addition, there hasn't been any report, to our knowledge, of incidents where VO consumption resulted in sickness.

[5] Suppliers interviewed indicated that the plugs are not designed for pouring but only for sealing the cans after they are filled with oil. There however seems to be a misunderstanding with implementing partners who expect to be able to pour oil from the plugs but end up having to poke holes in the cans instead.

The introduction of foreign objects in the cans may cause food safety concerns, although VO is typically cooked and there has not been any report of food safety incidents associated with this practice. Oil vendors interviewed indicated that the plugs are not designed for pouring but for sealing the cans after filling. One vendor previously used pull-out spouts (Picture 5). Yet, implementing partners and recipients did not use the pull-out spout because the opening was too small and distribution was taking too long due to the poor air flow.

Picture 5: Pull-out spout previously used by an oil vendor

Photo credit: FAQR

II.c. Potential Alternative Packaging Options

Based on the challenges discussed, three main objectives have been identified for the packaging of VO: 1) reducing packaging breakage and leakages; 2) standardizing and harmonizing the size of the cans to facilitate procurement, shipping and storage; and 3) investigating the best container design to improve functionality.

Six packaging options were tested as part of this study. The six packaging options selected here are packaging technologies which have been discussed with VO vendors and packaging suppliers during previous meetings. However, they are not an exhaustive list of the possible packaging options available.

Table 1: Main characteristics of potential options considered for VO packaging

	Option 1**	Option 2**	Option 3	Option 4**	Option 5	Option 6
Material**	Metal	Metal	Metal	Metal	Metal	Plastic (PET)
Shape	Round	Round	Round	Round	Rectangular	Rectangular
Individual ration size	No	No	No	No	No	Possibly
Closure	Plug 1	Plug 2	None (plain top)	Plug 1	Pull-out spout	Twist-on cap
Standard food packaging	No	No	Yes (food)	No	No	Yes (oil)

* Options 1, 2 and 4 have different dimensions and ridges profiles.
** It is unknown whether the metal options are made of the same metal grade and thickness, which could play a role in their performance and price.

III. STEPS TO ASSESSING VO PACKAGING OPTIONS

III.a. Comparing Costs

An increase in costs could negatively impact USAID's procurement budget and directly impact the number of recipients reached. Costs are therefore critical when assessing new packaging options. The price of packaging itself needs to be considered, but new packaging types will also result in changes in operations, transport and storage costs, which may outweigh the benefits or disadvantages of some technologies considered. Because of this, it is necessary to evaluate the cost of alternative packaging options at every step of the supply chain and the impact that each would have on the total cost of a food aid program.

The FAQR team built a cost matrix to compare the expenses associated with different packaging options. The packaging characteristics and the cost of the food, containers and operation are entered by the user. The price of international freight, inland transport and storage are automatically calculated based on the data collected during FAQR's field study in Burkina Faso. Annex a. details the calculations and sources of information. The results estimate the price of getting the foods from the U.S. vendors to the food distribution points in Burkina Faso as if they were distributed in the context of the study (13). *The costs do not represent the average cost of sending U.S. food aid products to any food distribution point, but they do provide an opportunity to compare the costs associated with different packaging options in the same context–a blanket feeding program in Northeastern Burkina Faso.*

The cost matrix also allows the user to enter the cost of prepositioning the food, the cost of transport from the supplier's facility to the port, and any additional inland transport and storage costs depending on the number of secondary warehouses that the foods go through in-country.

In addition, the cost matrix includes a "sensitivity analysis" section to assess what the price of the primary packaging would need to be in order for the transition to a new packaging option to be cost-neutral–i.e., how much each primary packaging option should cost so the switch to this option would result in the same total spending per MT than the control. The sensitivity analysis provides a sense of what the price of packaging would need to be for the new options to be economically viable. Users can apply their expertise to assess whether the target prices are achievable[6]. The sensitivity analysis is also conducted on the cost of international freight.

The full cost matrix is pictured in Table 2.

[6] For example, if there is a 30 percent difference between the estimated price of packaging and the target price for a cost-neutral transition, it seems unlikely that the price could be brought down to avoid an increase in total costs. However, if a 5 percent decrease would lead to a cost-neutral transition, one could argue that it may be possible to negotiate the prices with suppliers and/or that the possible error in the estimates may eventually lead to equivalent total spending.

Table 2: Blank cost matrix for the comparison of the costs associated with new packaging options*

	Control	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Primary packaging - weight content (kg)	3.68						
Primary packaging - unit/MT (units)	271.74	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Primary units per packaging system (units)	6						
Secondary packaging - unit/MT (units)	45.29	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Packaging system dimensions - width (ft.)	-						
Packaging system dimensions - depth (ft.)	-						
Packaging system dimensions - height (ft.)	-						
20-ft container - packaging systems/cont.	746						
20-ft container - MT/container	16.47	0.00	0.00	0.00	0.00	0.00	0.00
	Food & Packaging costs						
Cost of bulk food product ($/MT)	$736.09						
Operation costs ($/MT)	$200.00						
Cost of primary packaging ($/unit)	$1.00						
Total primary packaging cost ($/MT)	$271.74	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Cost of secondary packaging ($/unit)	$1.00						
Total secondary packaging cost ($/MT)	**$45.29**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
	Prepositioning costs						
Prepositioning costs ($/MT)	-	-	-	-	-	-	-
	Shipping costs						
Transport to U.S. port (S/MT)	-	-	-	-	-	-	-
Shipping cost per 20 ft container	$6,121.00	$5,631.32	$5,631.32	$5,631.32	$5,631.32	$5,631.32	$5,631.32
Shipping costs per MT	$371.61	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Ground transport to final destination (internal transport)						
Inland transport ($/MT/km) - to 2nd warehouse	-	-	-	-	-	-	-
Inland transport ($/MT) - to 2nd warehouse	-	-	-	-	-	-	-
Inland transport ($/MT/km) - to food distribution point	$0.21	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Inland transport ($/MT) - to food distribution point	**$61.74**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
	In-country Storage Costs						
Capacity of warehouse (MT)	**2,336.56**	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Storage costs ($/MT)	**$25.14**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
	TOTAL COST						
	Control	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**
Total cost ($/MT)	**$1,712**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Yearly cost (FY17)	$143,932,593	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Cost difference ($/FY) vs. control	-	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
	Sensitivity Analysis - Packaging costs						
		Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**
Target cost ($/can) for cost-neutral transition		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Difference with estimated unit price ($/can)		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Percent change		**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
	Sensitivity Analysis - International transport						
		Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**
Target shipping cost ($/MT) for cost-neutral transition		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Target shipping cost ($/container) for cost-neutral transition		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Percent change		**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.

III.b. Testing Packaging Performance

Feedback from stakeholders suggests that the performance of the current packaging technologies used for food aid products is inadequate. Recurring issues leading to losses and breakages indicate that the packaging technologies currently used do not provide the level of protection required to effectively transport the foods from the U.S. suppliers' facilities to the recipients' homes.

Standard packaging performance tests exist but do not reflect the roughness of the food aid supply chain. To remedy this, a protocol was designed in partnership with Westpak, Inc. (14) to better represent food exposure conditions throughout the food aid supply chain. Food aid products are packaged in a range of different container types, including: cans in boxes, individual sachets (about 100 g) in boxes, small bags (about 1.5-2 kg) in boxes, and large bags (25-kg or 50-kg). The protocol summarized in Table 3 and further outlined in Annex b. was designed for VO packaging testing (cans or bottles in boxes), but some of these tests may need to be slightly altered or others may need to be included for testing other packaging types.

Table 3: Protocol for testing the performance of packaging–boxed food products

Test	Duration	Description	Samples–for each packaging option
Climatic Conditioning	72 hours	The packaging systems are placed in a chamber at 45 degrees Celsius and 85% relative humidity to simulate the environment to which they may be exposed throughout the supply chain.	3 boxes of cans/bottles filled with VO
Vibration Testing (secured packages)	120 minutes	Random vibration to replicate ocean transport.	Same as above
Loose Load Vibration Testing (loose packages)	180 minutes	Vibration testing to replicate road transport in-country (equivalent to 1,350 miles travelled).	Same as above
Freefall Drop Testing	5 drops	5 drops from 48 inches high on the base, one side, one corner, one edge and the top of the box.	**One of the 3 cases** previously subjected to vibration testing
	5 drops	5 drops from 48 inches high on the base, side, bottom edge, top edge and top of the can/bottle.	**A single can or bottle taken from one the 2 remaining cases** previously subjected to vibration testing
Climatic Conditioning	72 hours	The packaging systems are placed in a chamber at 45 degrees Celsius and 85% relative humidity to simulate the environment to which they may be exposed throughout the supply chain.	3 boxes of empty cans/bottles
Compression Strength Testing[7]	To failure	Compression test to failure per ASTM D642-15.	The 3 cases of empty cans/bottles previously preconditioned

It is important to note that this protocol was designed to try to replicate some of the conditions and challenges to which the foods are exposed during transit between the U.S. supplier and the

[7] The compression strength test was designed to be conducted on the packaging systems (cans or bottles in the cartons) to represent the stacking of the boxes during storage. However, the strength of the packaging system is higher than the strength of individual containers and may be higher than the machine's limits. If the first sample for a packaging option reaches the machine's limits, three cans or bottles should be taken out of an untested box and be tested separately. If the packaging system does not reach the machine's limit and the box and containers yield, then the individual containers do not need to be tested. Instead, the remaining two packaging systems for that configuration will be tested.

recipients' homes. However, this does not exactly replicate a true food aid supply chain. Passing these tests does not guarantee that the foods would make their final destinations. Failing these tests does not mean that the packaging technologies should be discarded completely. This protocol provides a valuable starting point to compare the performance of different options and identify those which seem more resistant than others. It also provides the suppliers with insight regarding the weaknesses of their current packaging solutions.

Based upon the results of the tests, a performance score can be calculated. Table 4 outlines the scoring criteria. The overall performance grade can be calculated by taking the average of the three test scores.

Table 4: Performance rating*

	+2	+1	0	-1	-2
Vibration testing (Transport)	No trace of leakage after both vibration tests	Stained box after >120 minutes of road transport	Leakage appear during 80 to 120 minutes of road transport	Leakage appear during 0 to 80 minutes of road transport	Leakage appear during ocean transport
Drop testing (Handling)*	No trace of leakage after 5th drop	Leakage after 5th drop	Leakage appears on box and can/ bottle after 2 to 4 drops	Significant losses after 2 to 4 drops (cannot continue)	Significant losses after the first drop
Compression strength (Storage)	Compression strength > 20-layer equivalent	Compression strength 18 to 20-layer equivalent	Compression strength 16 to18-layer equivalent	Compression strength 15 to16-layer equivalent	Compression strength < 15-layer equivalent

* The drop test score was evaluated based on the drop testing of the full box. The result of the drop test conducted on the individual can or bottle was used to round up or round down the score.

III.d. Assessing Functionality

Functionality must also be considered and evaluated. Packaging technologies should contribute to getting the foods from the U.S. vendors' plant to the point of consumption as efficiently as possible. The full food aid supply chain should be considered and the functionality of the packaging options should be assessed at each step. If a packaging solution optimizes shipping but complicates operations in the field, for example, it may not be a viable option.

It is important to note that there are several overlaps between costs or performance and functionality. For example, a packaging option which optimizes handling is functional but may also reduce transportation costs. On the other hand, a packaging solution practical for the food supplier (i.e. does not require changes to the supplier's production line) will most likely result in lower costs. Although it is important to take a holistic approach, these overlaps should be noted so they do not end up weighing disproportionally in the final cost-effectiveness evaluation. Table

5 only includes functionalities which are not embedded within other elements of the cost and performance assessments. The full list of functionalities to consider is detailed in Annex c.

It is challenging to put a value on functionality–the potential gains or drawbacks are not always quantifiable and can be subjective. In addition, they may vary depending on the stakeholder conducting the evaluation. Because of this, we suggest evaluating the functionality of potential new packaging options in comparison to the current packaging used (control). The scale below can be used to rank the packaging options based on their functionalities.

Much better than current: +2 Better than current: +1 Same than current: 0 Worse than current: -1 Much worse than current: -2

Table 5: Desired packaging characteristics at each step of the food aid supply chain and functionality score[8]

Functionality	Advantage	Score
Handleability by warehouse workers[9]	The box can be moved efficiently by warehouse workers, saving time and decreasing risk of damage.	
Distribution practicality	The can or bottle design reduces time at the distribution site by facilitating pouring, sharing, etc.	
Usage practicality	The can or bottle design facilitates handling and use by the recipients.	
Food safety	The can or bottle design decreases food safety concerns.	
Dual purpose	The box and can or bottle can be reused for other purposes (storage container, building material, transport of goods, etc.).	
Reduction in packaging waste generation	The box and can or bottle design and material minimize the amount of waste generated.	
Overall environmental impact[10]	The packaging technology used minimizes the overall environmental impact of food aid packaging (including packaging manufacturing, transport optimization, end-of-life waste generation, etc.).	
Total functionality score	***Average of the 7 scores above***	

III.e. Evaluating Cost-Effectiveness

Packaging technologies should be assessed on the basis of cost-effectiveness, which combines overall prices, performance and functionality considerations, rather than just cost alone. New packaging technologies being considered are likely to increase net costs and could result in USAID spending more on procurement. However, part of these costs could be offset by potential reductions in the amount of food wasted or by efficiency gains. If a packaging option increases that product's price but significantly limits food safety concerns, extends shelf life or reduces waste generation, it could very well be worth the investment.

Cost-effectiveness can be partially evaluated by considering the losses which could be prevented by switching to a new packaging option and gauging whether the reduction outweighs the possible

[8] The list below was drafted based on feedback from stakeholders at all levels of the supply chain and highlights the main considerations that were discussed.

[9] The ease of handling may slightly affect labor at the warehouse level and therefore affect storage costs. However, for this analysis, the cost of warehousing was adjusted for space occupation only and handling is therefore part of the functionality assessment.

[10] As there is ongoing debate regarding the use of metal vs. plastic packaging, the environmental impact of packaging should be considered. Plastic is generally recognized as less durable and therefore generating more waste, which can create image and environmental pollution issues in areas where waste management systems are lacking. However, the entire life cycle of packaging–from raw material sourcing to disposal–should be considered when evaluating packaging sustainability.

price increases. For example, if a new packaging raises costs by $1 million per year but decreases losses by the same amount, the higher cost could be warranted. However, it is not possible to predict how much a packaging technology will decrease losses. Even if the testing described above provides insights on the relative performance of each packaging option, the potential reduction in losses associated with each of these packaging options cannot be quantified. Instead, the amount of losses necessary to be prevented to offset the added cost associated with the new packaging options is calculated. The user of the tool can use their judgement and experience to decide whether that reduction is achievable. The amount of losses which would need to be prevented is calculated using the total cost of each option (which includes international and inland transport, and storage) and the price of the packaged food only (food, packaging and operations), which is the price that USAID would pay to the supplier. The actual value of the lost food falls within that range, depending on where in the supply chain the food is wasted. A similar calculation was done to assess the amount of reconditioning which would need to not happen to offset the increase in cost. The calculations are detailed in Annex d.

These calculations evaluate the impact that performance would have on cost-effectiveness. However, evaluating the role of functionality in cost-effectiveness is more challenging. There is no predefined metric to assess functionality, which can, in part, be considered a utility function – a component linked to what each stakeholder would prefer or would find more convenient—but without a direct implication on costs. In addition, different stakeholders could find some components more important than others and these components may not always be compatible. For example, a transporter might favor large bags which accelerate operations, while implementing partners prefer small, individual bags which can be handled easily by the food aid recipients at the distribution points.

Another way to assess cost-effectiveness is to grade costs, performance and functionality, and identify the packaging option which has the highest score. Table 6 proposes a grading scale for each component.

Table 6: Grading costs, performance and functionality to evaluate cost-effectiveness

	+2	+1	0	-1	-2
Costs	Decrease by more than $3 million	Decrease by $0.5-3 million	Within $0.5 million of control	Increase by $0.5-3 million	Increase > $3 million
Sensitivity analysis	-	-	**For options with negative costs scores:** If target packaging price is within 10% of the estimated price, add 0.5 to the costs score (-2 becomes -1.5, and -1 becomes -0.5)		
Performance	Average performance score >+1.5	Average performance score between +0.5 and +1.5	Average performance score within +/- 0.5	Average performance score between -0.5 and -1.5	Average performance score < - 1.5
Cost offset	**For options with positive performance scores:** If cost increase is offset with a <1% decrease in losses or <10% decrease in reconditioning, add 0.5 to the performance score.			-	-
Functionality	Average functionality score >+0.5	Average functionality score between 0 and 0.5	Average functionality score = 0	Average functionality score between 0 and -0.5	Average functionality score < -0.5

The total cost-effectiveness score for each option is calculated using the following equation:

Equation 1: Cost-effectiveness (CE) evaluation

$$CE = \frac{[costs + sens.anal.] + [perf. + cost\ off.] + [funct.]}{3}$$

However, the three components may need to be weighted to reflect priorities. How much weight to assign to each option should be discussed with the decisionmakers. The weights used here are for illustrative purposes and to be used as a starting point only. We propose that costs account for 40 percent of the cost-effectiveness score, performance for 30 percent and functionality for 30 percent. We estimate that cost remains the driving factor in packaging decisions: a packaging option which considerably increases cost is most likely not a valuable option considering the budget restrictions which typically constrain food aid programs. However, the stakeholder seeking to make a packaging decision may need to adjust how they choose to weight each component depending on their objectives. The weighted cost-effectiveness score can be calculated using this equation:

Equation 2: Weighted cost-effectiveness (CE) evaluation

$$CE_{weighed} = [costs + sens.anal.] * 0.40 + [perf. + cost\ off.] * 0.30 + [funct.] * 0.30$$

IV. PRELIMINARY RESULTS–VO PACKAGING CASE STUDY

IV.a. Cost Comparison

IV.a.1. Cost Assessment

The cost information used in this analysis does not reflect current costs practices. The price of packaging for the control was set at $1 per can and $1 per box.[11] The price of the six packaging options was estimated in relation to the control. (Please note that all costs/prices are in U.S. dollars.)

The prices associated with each packaging option were estimated and compared to the control. Table 7 and Figure 1 summarize the main cost components for the control and for the six potential alternative technologies.

When accounting for VO, operations, packaging, ocean transport, inland transport and storage costs, Option 6 is the cheapest option by far and could save $6 million per year if all suppliers were to switch to this packaging technology. The savings appear to come from the reduced price of packaging, which is $130/MT cheaper than the control. Option 2 has only slightly less expensive packaging and shipping costs than the control but it could add up to almost $1 million saved per year. The cost of shipping for Option 5 is significantly less than the control, but the increase in the price of packaging lead to an overall $2.7 million increase. Switching to Option 3 would increase costs by about $2 million, and Options 1 and 4 would result in $6 million and $3.5 million increases, respectively.

[11] In FY 2017, U.S. suppliers packaged VO in two different types of cans. The FAQR team was able to obtain information on the volumes packaged in each type of can and the average price of packaging was calculated. It was then normalized so the price of one control can was $1, and the price of one control box was $1. The price of each packaging unit was then estimated in relation to the normalized control.

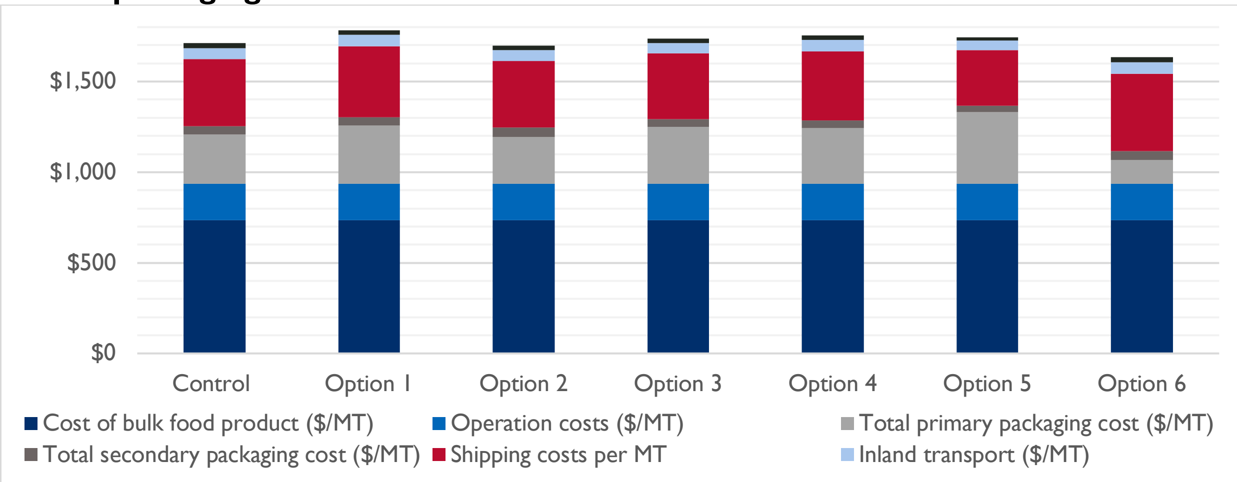
Table 7: Comparison of the costs associated with each option considered for the packaging of VO*

	Control	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Primary packaging - weight content (kg)	3.68	3.68	3.68	2.86	3.48	3.48	1.31
Primary packaging - unit/MT (units)	271.74	271.74	271.74	349.65	287.36	287.36	763.36
Primary units per packaging system (units)	6	6	6	6	6	6	9
Secondary packaging - unit/MT (units)	45	45.29	45.29	58.28	47.89	47.89	84.82
Packaging system dimensions - width (ft.)	-	1.69	1.61	1.57	1.68	1.16	1.06
Packaging system dimensions - depth (ft.)	-	1.13	1.11	1.05	1.13	1.07	0.84
Packaging system dimensions - height (ft.)	-	0.73	0.86	0.60	0.66	0.83	0.94
20-ft container - packaging systems/cont.*	746	706	756	1008	770	978	1296
20-ft container - MT/container	16.47	15.59	16.69	17.30	16.08	20.42	15.28
	Food & Packaging costs						
Cost of bulk food product ($/MT)	$736.09	$736.09	$736.09	$736.09	$736.09	$736.09	$736.09
Operation costs ($/MT)	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00
Cost of primary packaging ($/unit)	$1.00	$1.18	$0.95	$0.89	$1.07	$1.38	$0.17
Total primary packaging cost ($/MT)	$270.65	$320.65	$258.15	$312.69	$306.44	$395.52	$129.00
Cost of secondary packaging ($/unit)	$1.00	$1.02	$1.12	$0.73	$0.91	$0.75	$0.61
Total secondary packaging cost ($/MT)	**$45.11**	**$46.20**	**$50.64**	**$42.45**	**$43.51**	**$36.04**	**$51.76**
	Prepositioning costs						
Prepositioning costs ($/MT)	N/A**	N/A	N/A	N/A	N/A	N/A	N/A
	Shipping costs						
Transport to U.S. port (S/MT)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Shipping cost per 20 ft container	$6,121.00	$6,094.74	$6,127.56	$6,292.98	$6,136.75	$6,273.29	$6,482.02
Shipping costs per MT	$371.61	$390.98	$367.09	$363.81	$381.70	$307.20	$424.22
	Ground transport to final destination (internal transport)						
Inland transport ($/MT/km) - to 2nd warehouse	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Inland transport ($/MT) - to 2nd warehouse	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Inland transport ($/MT/km) - to food distribution point	$0.21	$0.22	$0.21	$0.20	$0.22	$0.17	$0.23
Inland transport ($/MT) - to food distribution point	**$61.74**	**$65.24**	**$60.92**	**$58.79**	**$63.25**	**$49.80**	**$66.56**
	In-country Storage Costs						
Capacity of warehouse (MT)	2,336.56	2,513.18	2,292.40	2,734.79	2,668.26	3,221.39	2,242.80
Storage costs ($/MT)	**$25.14**	**$23.38**	**$25.63**	**$21.48**	**$22.02**	**$18.24**	**$26.19**
	TOTAL COST						
	Control	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**
Total cost ($/MT)	**$1,710**	**$1,783**	**$1,699**	**$1,735**	**$1,753**	**$1,743**	**$1,634**
Yearly cost (FY17)	$143,825,954	$149,896,379	$142,832,113	$145,926,496	$147,413,882	$146,563,180	$137,391,857
Cost difference ($/FY) vs. control	-	**$6,070,425**	**-$993,841**	**$2,100,541**	**$3,587,928**	**$2,737,226**	**-$6,434,097**
Sensitivity Analysis - Packaging costs							
		Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**
Target cost ($/can) for cost-neutral transition		$0.91	$0.99	$0.82	$0.92	$1.26	$0.27
Difference with estimated unit price ($/can)		-$0.27	$0.04	-$0.07	-$0.15	-$0.11	$0.10
Percent change		**-22.51%**	**4.58%**	**-7.99%**	**-13.92%**	**-8.23%**	**59.31%**
Sensitivity Analysis - International transport							
		Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**
Target shipping cost ($/MT) for cost-neutral transition		$318.79	$378.90	$338.83	$339.03	$274.65	$500.73
Target shipping cost ($/container) for cost-neutral transition		$4,969	$6,325	$5,861	$5,451	$5,609	$7,651
Percent change		**-18.46%**	**3.22%**	**-6.87%**	**-11.18%**	**-10.60%**	**18.04%**

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.

**The information marked "N/A" was not available at the time of publishing this report or was not applicable to the FAQR field study in Burkina Faso.

Figure 1: Comparison of the costs associated with each packaging option considered for VO packaging*



* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.

It is important to highlight limitations to this comparison. Prices vary depending on order size, terms of the contracts, relationships with the vendors, etc. Because of this, obtaining accurate cost estimates is challenging. In addition, oil vendors may have to invest in equipment or adjust their production line to accommodate the new packaging technologies which could result in them increasing their prices, at least until their investments are amortized.

Operations costs at the oil vendor level are unknown. They were estimated to be approximately $200/MT but they may vary depending on the packaging type. It was also assumed that the 20-foot containers were loaded to their maximum capacity during transport. Although in some cases additional weight restrictions apply for road transport and containers were not filled to capacity. This could negate some of the shipping costs savings or increases. Finally, the costs associated with storage at secondary warehouses, distribution sites and during distribution are unknown.

This comparison, however, does demonstrate that the packaging decision has important implications on food aid costs.

IV.a.2. Sensitivity Analysis

The main contributors to total cost, aside from the price of VO itself, are international transport and primary packaging (bottles and cans). The figures used in the analysis were based on the information available, but some of the costs had to be estimated. As a result, there may be approximations. A sensitivity analysis was conducted to assess how the uncertainty in packaging and shipping costs could impact the results of the price comparison. In addition, it indicates what these costs would need to be for the transition to a new packaging option to be cost-neutral. Stakeholders can assess whether these targets could be reached.

The price of cans and bottles represents between 8 percent and 23 percent of the total cost (Annex e.). A change in packaging prices could therefore have a significant impact on total cost.

In order for the transition to the new packaging options to be cost-neutral, the prices of Options 1, 3, 4 and 5 would need to decrease by 7 to 27 cents per unit (Table 8). The price of Options 4 and 1 would need to decrease by 14 percent and 23 percent respectively, which is unlikely to be possible. However, Options 5 and 3 would need to see their prices drop by about 8 percent, a significant drop but one which can arguably be reached through negotiations with suppliers and also, if the price of packaging was slightly overestimated. Option 6 could see its cost double and still lead to cost savings. Option 2 could also see a slight cost increase (of about 5 percent) and still remain more affordable.

Table 8: Target primary packaging and international transport costs for each packaging option for a cost-neutral transition*

Sensitivity Analysis - Packaging costs						
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Target cost ($/can) for cost-neutral transition	$0.91	$0.99	$0.82	$0.92	$1.26	$0.27
Difference with estimated unit price ($/can)**	-$0.27	$0.04	-$0.07	-$0.15	-$0.11	$0.10
Percent change**	-22.51%	4.58%	-7.99%	-13.92%	-8.23%	59.31%
Sensitivity Analysis - International transport						
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Target shipping cost ($/MT) for cost-neutral transition	$318.79	$378.90	$338.83	$339.03	$274.65	$500.73
Target shipping cost ($/container) for cost-neutral transition	$4,969	$6,325	$5,861	$5,451	$5,609	$7,651
Percent change**	-18.46%	3.22%	-6.87%	-11.18%	-10.60%	18.04%

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.
** Negative numbers indicate costs decreases from the estimated cost, and positive numbers indicate costs increases.

International transport is also one of the main cost contributors, accounting for 18 to 26 percent of the total price (Annex e.). In order for the transition to the new metal packaging to be cost-neutral, shipping costs would have to decrease by 7 to 18 percent for Options 1, 3, 4 and 5 (Table 8). The shipping cost for Options 2 and 6 could increase by 3 percent and 18 percent, respectively, and would remain cheaper than overall costs.

IV.b. Testing Performance

IV.b.1. Transport and Handling Simulation

As initially designed, the protocol intended to place the samples under a hot and humid conditioned atmosphere meant to replicate the food aid products' typical environment. The testing equipment does not permit conducting testing under controlled conditions, so the boxes were taken out of the chamber after 72 hours under the controlled atmosphere and were tested at room temperature. However, because of the number of samples and clean-up time, the test ended up taking 20 days during which the samples remained at room temperature. Because of this, the samples were no longer under the influence of the controlled atmosphere at the time of the test.

For each packaging option, three boxes containing six cans or nine bottles filled with vegetable oil were tested. The boxes were subjected to two vibration profiles to replicate ocean and road transport on unpaved roads (referred to as "Ocean transport" and "Road transport"). Table 9 summarizes the results of the tests.

Table 9: Results of the vibration testing*

	Vibration testing – Ocean transport	Vibration testing – Road transport (loose load)	
		Time (min) until observation for each box	*Observation*
Option 1	No leakage observed	No leakage observed	
Option 2	No leakage observed	50, 50, 50**	Leaking of all cans at body (for all 3 boxes)**
Option 3	No leakage observed	39, 22, 22	Leaking of 1 can at bottom seam (box 1) Leaking of 2 middle cans at base of body/seam (boxes 2 and 3)
Option 4	No leakage observed	85, 85, 85**	Leaking of all cans at body (for all 3 boxes)**
Option 5	No leakage observed	136, 173, n/a	Leaking of 1 can at body (box 1) Leaking of 1 can at bottom corner edge/seam (box 2) No leakage observed (box 3)
Option 6	No leakage observed	85, 53, 66	Leaking of 1 bottle at base corner (for all 3 boxes)

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.
** Options 2 and 4 were the first to be tested and were not pulled out from the test until all the cans leaked. The other options were pulled out from the test as soon as leakage was visible so they could undergo drop testing. This is most likely the reason why all the cans were affected for Options 2 and 4, but not for the other options.

"Ocean transport" did not lead to any visible leakage on any of the packaging options tested. However, "road transport" resulted in significant leakage for many of the packaging options. Option 1 is the only option which showed no signs of leakage throughout the entire duration of the test. Option 5 also seemed to resist longer than the others, with one box showing no sign of leaking cans, and the other two boxes starting leaking after over two hours of testing. Leaking cans were noticed the fastest for Options 2 and 3, all within the first hour. Option 4 also showed significant traces of leakage (leakage most likely started earlier than 85 minutes, but testing continued until all cans were leaking). Option 6 started leaking after about one hour of testing.

Different types of damage were also observed. For Option 6, the only plastic option tested, all damages observed occurred at a bottom corner of the bottles (Picture 6). The damage to Option 3 was due to holes which formed near the bottom seam of the cans, most likely because of the rubbing of the cans against each other (Picture 7). The damage to Option 2 was exclusively due to dents in the body of the cans which led to the formation of holes (Picture 8), while the damage to Option 4 included both types of damage (Picture 9). Option 5 showed damage to the body of the cans and the bottom corner/seam (Picture 10). The damage to the corner did not seem to be due to the adjacent cans cutting it open, but rather to the corner seam getting "crushed," probably because of constant friction during the vibration test.

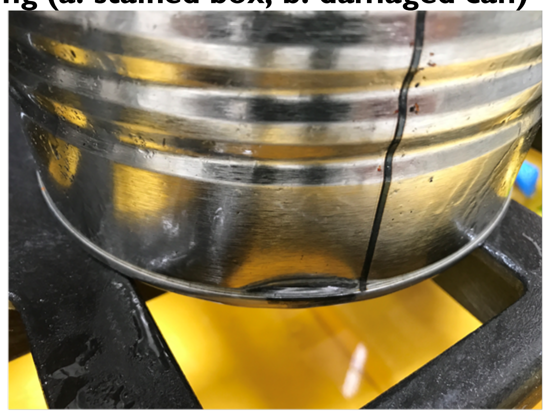
Picture 6: Option 6 after vibration testing (a. stained box, b. damaged bottle)

a. 

b. 

Picture 7: Option 3 after vibration testing (a. stained box, b. damaged can)

a. 

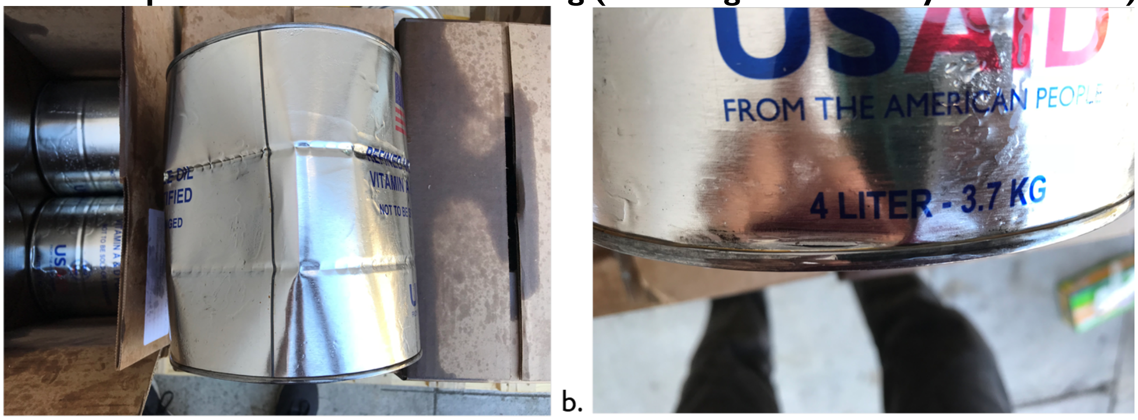
b. 

Picture 8: Option 2 after vibration testing

a. 

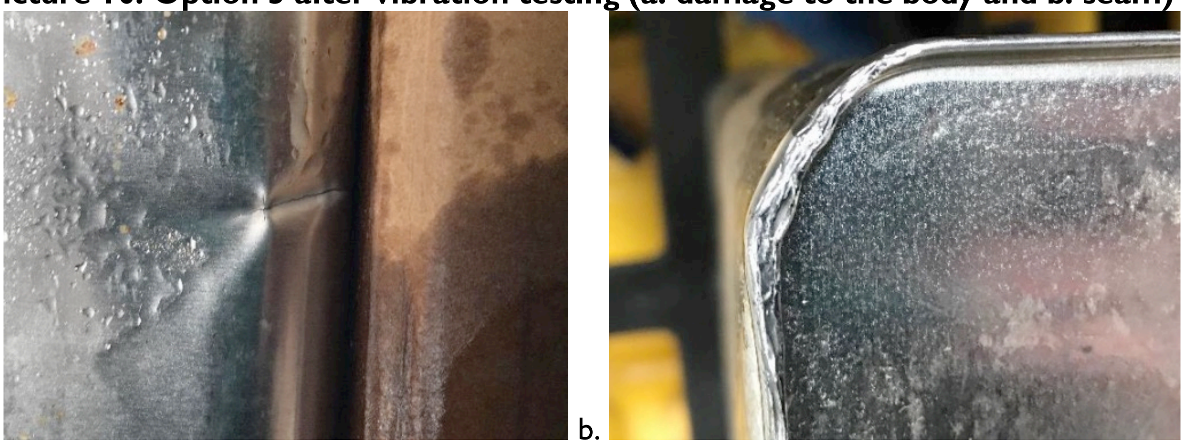
b. 

Picture 9: Option 4 after vibration testing (a. damage to the body and b. seam)



a. b.

Picture 10: Option 5 after vibration testing (a. damage to the body and b. seam)



a. b.

After vibration testing, packaging systems were subjected to drop testing. Both a full box and an individual can or bottle were drop tested for each packaging Option. Table 10 summarizes the drop-testing results.

Table 10: Results of the drop test*

	Time noticed	Observation
Option 1–box	After final drop	Very slight leak–origin unidentifiable (evidence based on box stains).
Option 1–can	n/a	No leak observed.
Option 2–box**	-	
Option 2–can*	-	
Option 3–box	n/a	No leak observed.
Option 3–can	After side (2nd) drop	Seam split open at top of can.
Option 4–box**	After top (5th) drop	One can leaked along the top seam/body.
Option 4–can**	After side (2nd) drop	Damage to body (Another can was tested, and the plug came out after the 4th [top edge] drop).
Option 5–box	After top (final drop)	Leakage at bottom corner of one can.
Option 5–can	n/a	No leak observed.
Option 6–box	After base (1st) drop	Leakage appeared at the bottom corner of a bottle after the 1st drop. The test continued until the third (corner) drop, when the box broke.
Option 6–bottle	n/a	No leak observed.

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.

** Options 2 and 4 were the first to be tested and were not pulled out from the test until all the cans leaked. The other options were pulled out from the test as soon as leakage was visible so they could undergo drop testing. The supplier of Option 4 provided samples of Option 4 with the current plug, which is the Option we were testing as part of this study, and samples with pullout spouts (Annex f.). We don't anticipate that the plug would play a role in the results of the drop test, so in order to be able to continue the evaluation, the results included in Table 10 for Option 4 are the results of the drop test for Option 4 with the pullout spout. Option 2 could not be drop tested.

Options 1 and 5 appeared to be the strongest, showing no sign of leakage until the final drop when the full box was drop tested (Pictures 11 and 12). When the can was tested individually, no damage was observed. Option 6 did not leak when a bottle was drop tested individually, but a bottle leaked from a bottom corner after the first drop when the whole box was tested (Picture 13). The box then broke on the third drop. On the contrary, no leakage was observed throughout the five-drop cycle for the box of Option 3, but when cans were tested individually, the top split open after the second drop (Picture 14). Finally, Option 4 had only one can leak at the end of the five-drop cycle on the box, but when an individual can was tested, damage to the body occurred after the second drop (Picture 15).

Picture 11: Option 1 after drop testing (a. cans in box, b. close-up of can damage)

a. 

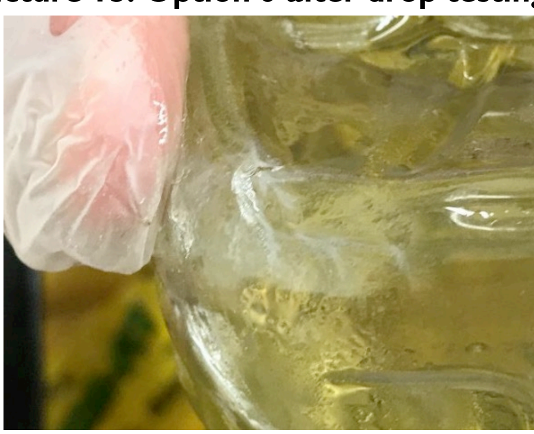
b. 

Picture 12: Option 5 after drop testing (a. damaged box, b. close-up of can damage)

a. 

b. 

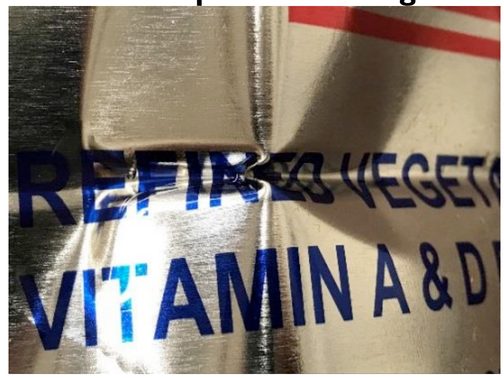
Picture 13: Option 6 after drop testing (a. damaged bottle, b. broken box)

a. 

b. 

Picture 14: Option 3–damaged can

Picture 15: Option 4–damaged can



IV.b.2. Storage Simulation

For each packaging option, three boxes containing six empty cans or nine empty bottles were stored at 45 degrees Celsius and 85 percent relative humidity for 72 hours before compression testing. The samples were removed from the chamber in batches so that they remained under the controlled atmosphere until the time of the compression test.

In some cases (Option 1, 2 and 3), the limit of the equipment (7,500 pounds) was reached before the packaging system yielded. In these cases, three individual containers were taken out of the other two untouched boxes and compression strength testing was conducted on the individual containers. Table 11 summarizes the results.

Table 11: Results of the compression strength test*

	Sample 1	Sample 2	Sample 3	Average	Layers equivalent
Option 1–box	>7520 lbs	-	-	**>7500 lbs**	**-**
Option 1–individual can	1533 lbs	1720 lbs	1789 lbs	**1681 lbs**	**184**
Option 2–box	>7509 lbs	-	-	**>7500 lbs**	**-**
Option 2–individual can	1884 lbs	1639 lbs	1828 lbs	**1784 lbs**	**191**
Option 3–box	>7525 lbs	>7521 lbs	>7504 lbs	**>7500 lbs**	**-**
Option 3–individual can**	1624 lbs	1684 lbs	1560 lbs	**1623 lbs**	**227**
Option 4–box	7093 lbs	7075 lbs	>7522 lbs	**>7230 lbs**	**>139**
Option 5–box	6632 lbs	6675 lbs	6302 lbs	**6536 lbs**	**125**
Option 6–box	481.6 lbs	442.6 lbs	474.3 lbs	**466 lbs**	**15**

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.

** All three boxes for Option 3 were tested before we decided to adjust the protocol and to test individual cans if the boxes didn't yield. The individual cans therefore had already been exposed to 7,500 pounds of pressure when tested as part of the entire packaging system. For Options 1 and 2, a first box was tested but when it didn't yield, three cans were taken out of the untouched boxes and tested individually.

Based on the results of the compression strength test, it is possible to assess how high (i.e. how many layers) the boxes can be stacked using Equation 3, which follows.

Equation 3: Estimation of compression strength in number of layers

$$Layers = \left(\frac{box\ comp.strength}{weight\ of\ box}\right) - 1\ \boldsymbol{or}\ \left(\frac{can\ comp.strength * nbr\ of\ can\ per\ box}{weight\ of\ box}\right) - 1$$

As stated previously, to optimize warehouse space, the foods are often stacked very high, and workers often climb on the boxes to reach the top of the stacks. Compression strength is therefore critical. Pictures and feedback from the field seem to indicate that the boxes are typically stacked between 15 and 20 layers high. Because the compression strength of Options 1 to 5 is significantly higher than this, we do not anticipate that stacking would result in damage. However, the compression strength of Option 6 seems to suggest that it should not be stacked as high as the metal options.

IV.b.3. Performance Score

The performance score of each packaging option was calculated according to the scoring system laid out in Table 4 and is shown here in Table 12.

Table 12: Performance score for each packaging option*

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Vibration testing	+2	-1	-1	0	+1	-1
Drop testing	+2	+1**	+1	+1	+2	-1
Compression strength	+2	+2	+2	+2	+2	-1
Performance Score	**+2**	**+0.7**	**+0.7**	**+1**	**+1.7**	**-1**

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.

** Options 2 did not undergo drop testing because the samples were eliminated after leakages occurred during vibration testing (leakages occurred for the other options as well but we began consolidating the cans and bottles which did not have holes into a single box so they could be drop tested). However, because Option 2 is also round cans with plugs, we anticipate that, assuming they are manufactured in the same way and the tin used is of the same thickness, they would behave the same way than Option 1 or Option 4 when drop tested. Since we chose the most conservative approach, the results for Option 4 were used.

IV.c. Functionality Assessment

As mentioned previously, functionality must also be considered when assessing packaging options. While functionality is often embedded in costs (i.e. vendors and contractors adapt their prices based on functionality or lack thereof), it is important to consider how the packaging options are going to impact operations, particularly at the end of the food aid supply chain where costs are relatively low but functionality is critical in order for operations to go smoothly. The table below summarizes how each packaging option compares to the control.

Table 13: Comparison of the functionality of each packaging option*, **

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Handleability–warehouse workers	0	0	0	0	0	-1
Distribution practicality	0	0	-1	0	+1	+2
Usage practicality	0	0	0	0	0	+2
Food safety	0	0	0	0	+1	+1
Dual purpose	0	0	0	0	0	-1
Decrease in packaging waste generation	0	0	0	0	0	-1
Overall environmental impact***	?	?	?	?	?	?
AVERAGE	**0**	**0**	**-0.2**	**0**	**+0.33**	**+0.33**

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.
** Scoring key: Much better than control: +2; Better than control: +1; Same than control: 0; Worse than control: -1; Much worse than control: -2.
*** The overall environmental impact of each option is unknown, so that facet was not included in the calculation.

Options 1, 2 and 4 are very similar to the control and would not result in a change in functionality. Their dimensions are slightly different, but they would be handled and used similarly to the control. The plain top of Option 3 could introduce some challenges in distribution—if implementing partners and recipients do use the plug for pouring, for example. We made the assumption that this wouldn't change usage practicality because recipients typically do not receive a full can of VO. The pull-out spout of Option 5 should improve distribution but for the same reason as stated in the Option 3 assessment, we do not believe that it would have a significant impact on usage since recipients most likely will not receive a full can. Option 5 could also potentially reduce food safety concerns by avoiding the need for tools to open the can. Because it could be used as a final ration size, Option 6 could significantly improve distribution and usage and should also reduce food safety concerns when compared to the control (and all of the other options considered) which require that they be transferred to containers brought by the recipients. It could, however, increase waste generation and reduce opportunities for repurposing because we anticipate that the packaging wouldn't be as durable as the control. Since there are more boxes per MT, we also anticipate that the handleability by warehouse workers would be slightly worse than the control.

Functionality must be carefully assessed and should ideally be discussed with stakeholders directly involved with the relevant activity. For example, distribution practicality should be assessed by implementing partners directly involved in food aid distribution. The foods are not always used in the field the same way the donors, suppliers and implementing partners intended, so usage practicality should be discussed with food aid recipients. The ranking above was determined based on the intended use, but the actual use may be different.

IV.d. Determining Cost-Effectiveness

IV.d.1. Potential Cost Offsets

Improvements in performance could lower losses and therefore offset some the cost increases and improve cost-effectiveness. Although the tests results provide an indication of each packaging option's potential performance, it is not possible to predict the exact amount of loss which would occur for each packaging option. An analysis was conducted to evaluate the amount of loss and reconditioning needed to offset the additional cost of new packaging.

The amount of loss which needs to be offset was calculated using both the cost of packaged VO (VO + operations + packaging) and the total cost (packaged VO + transport + storage) for each option. Table 14 summarizes the amount of loss which would need to be avoided every year to compensate for the anticipated price increases due to each of the new packaging options considered. When bearing in mind losses and total cost, Options 2 and 6 would remain more cost-effective than the control even with losses up to 580 MT and 3,900 MT respectively, or 0.70 percent and 4.68 percent of the total volume procured in FY 2017. The other options would need to prevent 1,200 to 3,400 MT of losses to make up for the increased cost due to the new packaging. These loss amounts represent between 1.4 percent and 4 percent of the total volume procured in FY 2017. Because there is no reliable data on losses available, it is difficult to assess how this compares to the current volumes lost. However, estimates discussed by agencies during presentations and meetings usually state that approximately 1 percent of the total volume procured is lost. In light of this, Options 1, 3, 4 and 5 would need to eliminate all losses, which is unrealistic. Even then, most of the options proposed would still result in cost increases. Option 6 could lead to a significant increase in losses and remain "cost-effective," but such a high volume of loss would introduce other challenges. If solely the price of packaged VO is considered, the volumes which need be preserved to offset the increases in costs due to the new packaging options represent an even larger portion of FY 2017 procurement.

Table 14: Losses which would need to be prevented each year to offset the cost of packaging*

Cost offsets - Losses						
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Losses (MT/FY) that need to be prevented to offset costs increases - using total cost**	**3,406**	**-585**	**1,210**	**2,047**	**1,571**	**-3,938**
--> Percent of total FY17 procurement**	4.05%	-0.70%	1.44%	2.43%	1.87%	-4.68%
Losses (MT/FY) that need to be prevented to offset cost increases - using cost of packaged oil**	**4,659**	**-798**	**1,627**	**2,790**	**2,001**	**-5,761**
--> Percent of total FY17 procurement**	5.54%	-0.95%	1.93%	3.32%	2.38%	-6.85%

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.
** A negative number indicates that even with an increase in losses up to that amount, the packaging option would remain more cost-effective than the control.

In addition to losses, VO must sometimes be reconditioned to avoid loss due to packaging damage. This requires implementing partners to buy new packaging locally and to spend time on reconditioning operations. In Burkina Faso, during a field study conducted by the FAQR team, it was estimated that labor and locally-procured packaging costs amounted to approximately

$450/MT of reconditioned VO. In Ethiopia, Catholic Relief Services (CRS) indicated that procuring packaging locally results in an additional $212/MT in packaging costs. They also estimated that it takes about ten minutes to recondition one carton of VO or about 7.5 hours of work to repackage one metric ton. Assuming that reconditioning operations cost on the average $331/MT, we can conduct a similar analysis to evaluate how much of these reconditioning activities would need to be eliminated to offset the cost of new packaging (Table 15).

Table 15: Amount of reconditioning which would need to be prevented each year to offset the cost of packaging*

	Cost offsets - Reconditioning					
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost of reconditioning ($/MT)	$331					
Reconditioning operations (MT) that need to be prevented to offset cost increases**	**18,340**	**-3,003**	**6,346**	**10,840**	**8,270**	**-19,438**
--> Percent of total FY17 procurement**	21.81%	-3.57%	7.55%	12.89%	9.83%	-23.12%

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.
** A negative number indicates that even with an increase in losses up to that amount, the packaging option would remain more cost-effective than the control.

The increase in cost for Options 1, 3, 4 and 5 is equivalent to the cost associated with reconditioning 6,000 to 18,000 MT of VO[12]. This represents 8 to 22 percent of the total volume procured in FY 2017. In Burkina Faso, 11 percent of the VO received must be reconditioned. Because of this, Option 3 and 5, which need to prevent the reconditioning of 7.55 percent and 9.83 percent of the volume procured in FY 2017, could be cost-efficient if their performance is significantly better than the control. When considering costs and reconditioning needs, Option 6 would be cost-efficient even if 19,000 MT of VO had to be reconditioned every year (although reconditioning such a large volume may result in other difficulties). Option 2 could also see a slight increase in the volume which needs to be reconditioned and remain cost-effective.

IV.d.2. Evaluating Cost-Effectiveness

Although the balance between cost and performance is a major component of cost-effectiveness, functionality should also be considered. Rather than putting a value on functionality which can be challenging, cost, performance and functionality were graded based on the criteria detailed in Table 6. An overall cost-effectiveness score was calculated for each option (Table 16).

[12] This is assuming that all the oil contained in the cans being reconditioned is transferred to a new container. However, there may be losses even when reconditioning the oil and the full four liters may not be salvaged.

Table 16: Grading costs, performance and functionality to evaluate cost-effectiveness*

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Costs	-2	+1	-1	-2	-1	+2
Sensitivity analysis	-	-	+0.5	-	+0.5	-
Performance	+2	+1	+1	+1	+2	-1
Cost offset	-	-	+0.5	-	+0.5	-
Functionality	0	0	-1	0	+1	+1
AVERAGE	0	0.7	0	-0.3	1	0.7
Total cost-effectiveness (CE) score**	-0.2	0.7	-0.05	-0.5	0.85	0.8

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.
**$CE = [costs + sens. anal.] * 0.40 + [perf + cost\ off.] * 0.30 + [funct.] * 0.30$

Based on our analysis, Option 5 appears to be the most cost-effective, followed closely by Options 6 and 2.

V. DISCUSSION

V.a. Main Findings for VO Packaging

Our research method identified Option 5 as the most cost-effective option for VO packaging, but decisionmakers must determine whether they want to revise how to weight the components in order to reflect their priorities. There is not one packaging option better than the others across all three categories (cost, performance and functionality) and switching to either of these options would have drawbacks. For example, Option 6 could result in significant cost savings, but its performance seems to be inferior to that of other packaging options. Option 3's performance is relatively good, but it introduces a number of functionality challenges. Considering this, it may help to move the foods effectively throughout the supply chain without having to deal with as much damage and losses, but this may make distribution less efficient. Option 2 would result in cost savings but it does not seem to perform as well as other options and does not address functionality challenges. The Table 17 summarizes the main findings for each cost-effectiveness component for each packaging option.

Table 17: Summary of costs, performance and functionality findings for each packaging option*

	Costs	Performance	Functionality
Option 1	Most expensive option–would lead to more than a $6 million increase.	Most performant option–excellent compression strength, no leakage observed during vibration testing and resistant to drop testing.	Same level of functionality as the control.
Option 2	Cheaper than the control, it could lead to almost $1.5 million in savings.	Excellent compression strength and presumably minor leakage resulting from drop testing but damage occurred early in vibration testing due to the cans getting dented/perforated as a result.	Same level of functionality as the control.
Option 3	More expensive than the control–it would lead to about a $2.1 million increase, which could be offset if the price of primary packaging decreased by 8%.	Excellent compression strength and resistant to drop testing. Damage during vibration testing due to cans rubbing against each other (cut holes near base of cans).	Some potential challenges in distribution when compared to the control due to the plain top but only if implementing partners use the plugs for pouring.
Option 4	Among the most expensive options–it would lead to about a $3.5 million increase, which could only be offset if the price of primary packaging decreased by 14%.	Good compression strength and minor leakage after drop testing, but damage occurred relatively early in vibration testing (due to the cans both getting dented and rubbing against each other).	Same level of functionality as the control.
Option 5	More expensive than the control–it would lead to about a $ 2.7 million increase, which could be offset if the price of primary packaging decreased by 8%.	2nd most performant option–good compression strength, little damage during vibration testing (signs of leakage at the very end of the test), and resistant to drop testing.	Potential improved distribution efficiency and decreased food safety concerns.
Option 6	By far the cheapest option–could save $6 million.	Worst performance–poor compression strength and damage occurred relatively early in vibration testing and drop testing. The base corners appear to be the weak points.	Improved distribution efficiency and usage by recipients and decreased food safety concerns. Potential increase in waste generation and decreased opportunities for repurposing.

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.

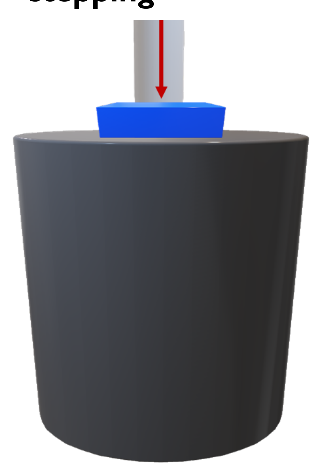
V.b. Next Steps for VO Packaging

The results described previously provide great insight about how the six packaging options considered compare to the control and to each other. Option 5 seems to be a promising solution which could address some of the challenges reported from the field and other stakeholders throughout the supply chain. However, further information is needed before moving forward and recommending that all oil vendors transition to a particular packaging solution. Prices need to be confirmed and official quotes must be received from vendors and contractors. Oil vendors must evaluate the investments they would need to make and how these would be reflected in overall operation costs. Transporters will also need to provide quotes to confirm that transport costs were accurately estimated. Implementing partners should be consulted to ensure that no other costs and distribution challenges were overlooked. Finally, before moving forward with a new packaging option, the suppliers must confirm that they have the capacity to produce the volumes needed based on USAID's projected procurement schedule.

Storage and inland transport costs were calculated based on a study that FAQR conducted in Burkina Faso. There, the foods went through a single warehouse prior to being brought to the food distribution sites. The inland transport costs include a single trip from the main in-country warehouse to the distribution sites, while foods sometimes transition through several warehouses before being distributed. The inland transport costs may therefore be underestimated and the gap between options which have the lowest transport costs and those with the highest transport costs may increase. Similarly, the storage costs were in a single warehouse, but transitioning through multiple warehouses may result in higher costs. Additionally, the cost of transport from the supplier's plant to the U.S. port was not included here but could be significant.

In addition, rather than discarding the options which scored poorly, it may be possible to make adjustments to some of the six options which were tested. Changing the closure system of Options 1, 2 and 4 to a pull-out spout could improve their functionality, although it would most likely increase costs. Adding a second opening to allow for air displacement could also improve pouring of the VO into the recipients' final containers. The dents which appeared during vibration testing seemed to be located along the ridges. It is possible that altering the ridge pattern on the cans may improve their resistance. A can supplier also designed a can with a base that is narrower than its body. This could eliminate the damage along the seams of the cans due to the cans rubbing against each other, although it may limit the number of suppliers capable of providing this option. The corners at the base of the rectangular PET bottles were the weakest point. Considering the use of round bottles could eliminate this weak point, although it would decrease space optimization.

Figure 2: Proposed design to test the plug's resistance to stepping



The method demonstrated here provides a way to compare different options but did not present a comprehensive review of all the packaging options available.

In addition, we also suggest including a test to explore the performance of the can closures. Feedback from the field has suggested that leakage occurs around the plugs, but this issue was not observed in our analysis of the packaging. A test could be developed to apply pressure around the plug via a rectangular block which would represent the foot of a worker. Approximately 180 to 200 pounds of force (roughly the weight of an average worker) would be applied and then removed, simulating someone stepping on the can. The force would be applied and removed five times to address the likelihood that the same box could be climbed on multiple times throughout the months it spends in storage. The boxes would then be inspected to assess whether the discontinued pressure created a gap around the plug which could lead to leakage. The proposed test is illustrated in Figure 2.

Shelf-life testing should also be conducted to confirm that the packaging options considered protect the integrity of VO until consumption by the recipients. Although there shouldn't be any major differences between the metal cans, transitioning to plastic containers could decrease shelf life. To our knowledge, there has never been a study which assessed the shelf life of VO at the time of distribution or at the time of consumption after exposure to field conditions. It is unknown whether VO retains its nutrition profile until distribution to and consumption by the recipients, which may have an impact on its effectiveness.

Performance and functionality must also be verified, and the technologies considered should be field-tested before being rolled out. This is the first study comparing the performance of different VO packaging options when exposed to field-like conditions. Concerns regarding the performance of the different packaging technologies has been raised but the exact nature of the damages and challenges experienced is unknown. The results of the performance tests provide great insight on the type of damage which can be expected in the field, but the sample size was small and may not accurately represent the nature and amount of damage which should be expected. The environment also varies greatly depending on the recipient population and implementing partner. Because of this, the environmental risks (i.e. climate, infrastructures, etc.) encountered may be lower or higher than simulated here. In addition, some damage such as infestation, rusting, etc. cannot be replicated in the lab.

Functionality also needs to be confirmed. Packaging may not be used as intended once it reaches the implementing partners and recipients, and what appears to be a useful functionality of the packaging design may not end up being relevant. Alternatively, we may have overlooked a functionality that is critical for field operations.

V.c. Adapting the Method to Other Commodities

VO is among the most expensive food aid products used by USAID. There are five main categories of products with different types of packaging:

1. Commodities bagged in 50-kg woven polypropylene bags;
2. Grains and fortified flours bagged in 25-kg multiwall paper bags;
3. Fortified flours in individual (approximately 1.5-kg) pouches and in corrugated boxes (typically 10 bags per box);
4. Ready-to-use foods in individual sachets and in corrugated boxes (typically 100 to 150 sachets per box); and

5. Vegetable oil in cans or bottles and in corrugated boxes.

The method presented here was designed to assess potential alternative packaging options for vegetable oil. With slight adjustments, it can be applied to other food aid products as well. Table 18 summarizes the main considerations for the other commodities.

Table 18: Additional considerations to assess packaging options for other food aid products

Packaging Type	Costs	Performance	Functionality
Bags (25- and 50-kg – *used for cornmeal and fortified flours, and for commodities respectively*)	Similar cost-analysis as VO, but the packaging system is the bag.	Vibration testing is not necessary but bags should undergo at least 10 drops instead of 5. Should include a puncture-resistance test and consider the bag's oxygen and water vapor transmission rates to reduce the risk of spoilage. Should evaluate the resistance to infestation.	Similar functionality assessment than for VO.
Small pouches in boxes (*used for some fortified blended foods [i.e. Super Cereal Plus]*)	Same cost-analysis as for VO but the potential cost offsets should not be considered (there is little performance issue with the current packaging).	Vibration testing is not necessary but boxes should undergo at least 10 drops instead of 5. Should include a puncture resistance test and test the seal resistance, plus consider the bag's oxygen and water vapor transmission rates to reduce the risk of spoilage. Should evaluate the resistance to infestation.	Similar functionality assessment as for VO but special attention should be paid to how the bags will impact food safety during in-home storage, and how they will impact usage and cooking practices.
Individual sachets (*used for high energy biscuits and lipid-based nutrient supplements*)	Same cost-analysis as for VO but the potential cost offsets should not be considered (there is little performance issue with the current packaging).	Vibration testing is not necessary but boxes should undergo at least 10 drops instead of 5. Should include a sachet puncture resistance test and test the seal resistance, plus consider the sachets' oxygen and water vapor transmission rates to reduce the risk of spoilage. Should evaluate the resistance to infestation.	Similar functionality assessment as for VO but special attention should be paid to how the bags will impact usage and disposal.

VI. CONCLUSIONS

The method described here proposes a novel approach to comparing different packaging options for food aid products. Challenges related to packaging can significantly alter the cost-effectiveness of food aid products but these cost-effectiveness losses are difficult to evaluate at every step of the supply chain. **To guide suppliers and decisionmakers in the packaging evaluation and revision process, the FAQR team drafted a comprehensive method for assessing packaging options. It includes costs, performance and functionality considerations and proposes a grading system which leads to the identification of the most cost-effective solution.**

The method was applied to six VO packaging options. This report is the first to present data which allows a comprehensive comparison of different VO packaging technologies. It was also the first time packaging options were subjected to lab testing which aims to recreate the food aid supply chain.

We identified Option 5—a rectangular can with a pullout spout—as the most cost-effective option but additional information and testing are necessary. Cost information must be confirmed and other options not considered in this report that may address remaining gaps should be evaluated following the same method. In addition, efforts must continue to collect reliable data in order to be able to better understand the reality of conditions in the field and to more accurately quantify the losses due to poor packaging.

Moving forward, we recommend the following approach and next steps to continue the ongoing efforts for food aid packaging revision:

Recommended Approach to the Revision of Food Aid Packaging:

1. Food aid and packaging suppliers must be regularly informed of the challenges faced in the field and must be provided with specific feedback regarding the causes of damage and losses.
    - *USAID has been engaging with suppliers in meetings and visits to initiate this collaborative process, but these conversations must continue and suppliers must be provided feedback on the quality and performance of their products.*
    - *The data collection system throughout the supply chain must be improved to obtain quantitative and qualitative information on the nature of losses occurring in the field.*
2. Food aid and packaging suppliers should be encouraged to propose packaging options which address current challenges.
    - *Food and packaging suppliers should be involved in the packaging-revision conversation. They have the technical expertise and resources to develop packaging options which address the challenges faced throughout the supply chain.*
    - *To encourage open-sourcing and to ensure that all potential packaging options are considered, both current and new suppliers should be invited to present solutions.*
3. The packaging options should be assessed following the method presented in this report to identify the most cost-effective options.
    - *It is critical to evaluate packaging options based on their overall cost-effectiveness to ensure that a comprehensive assessment is conducted.*
4. The most cost-effective options should be trialed in the field to confirm their cost-effectiveness before being rolled out.
    - *The performance and functionality of the packaging options must be confirmed when exposed to "real life" field conditions.*
    - *The shelf life of the products should also be assessed to confirm that the foods maintain their nutrition profile and overall quality until consumption by the recipients.*

VII. ANNEXES

VII.a. Cost Matrix Description

The cost matrix is a Microsoft® Excel-based table which guides the users in calculating the costs associated with each packaging considered.

- Packaging description (lines 3 to 9): Dimensions and content of the packaging units and boxes. The number of primary and secondary packaging units per MT are automatically calculated.
- Capacity of 20-foot container (lines 10 and 11): The user informs the number of boxes which can fit in one 20-foot container. The number of MT per 20-foot container is then automatically calculated.
- Food & packaging costs (lines 13 to 18): The user informs the anticipated costs of the food and operation as well as the price of the primary and secondary packaging. Total packaging price per MT is calculated automatically.
- Prepositioning costs (line 20): The user enters the cost of storing the foods in a prepositioning warehouse, if applicable.
- Shipping costs (line 22 and 23): The cost of transportation from the U.S. supplier to the port should be informed by the suppliers. The freight cost is automatically calculated based on a quote for shipping VO from Houston to Ouagadougou, Burkina Faso.
    - A freight forwarder indicated that it currently costs $6,121 to ship one 20-foot container from Houston to Ouagadougou. The freight forwarder also estimated that labor accounts for no more than 10 percent and confirmed that labor would most likely increase as the number of boxes per container increases. We took a conservative approach and estimated that labor was only 8 percent of the total shipping cost. The constant freight cost was therefore estimated to be 0.92 x 6121 = $5,508.9/20-foot container and was assumed to be constant regardless of the packaging type. The labor piece is estimated based on the number of boxes per container. The current labor cost is estimated to be 0.08 x 6121 = $489.68 for 746 cartons (the number of boxes per 20-foot container for the control). The labor cost for each technology is calculated using the following formula: labor cost = $612.1 x (the number of cartons per 20-foot container)/746. The total shipping cost per container is the sum of labor and freight costs. The cost per 20-foot container is then converted back to cost per MT.
- Inland transport costs (lines 26 to 29): In Burkina Faso, the foods didn't transition through a secondary warehouse. Inland transport is therefore automatically calculated based on the cost of transport from the main warehouse to the distribution points in Burkina Faso.
    - There, the cost of transport is $0.21/MT. This price was adjusted based on the number of boxes per 20-foot container (i.e. space occupation). In addition, in Burkina Faso, the total distance traveled was 294 kilometers. The total transport cost per MT is 294 x 0.21 x (the number of cartons per 20-ft container)/746.
- Storage costs (lines 31 and 32): Storage in the main warehouse is automatically calculated based on space utilization and cost information collected in FAQR's Burkina Faso study.
    - Warehouse dimensions in Ouagadougou were measured and the capacity was estimated to be 186,885.2 cubic feet. Based on the box dimensions, this is

converted to capacity in MT of VO. In Ouagadougou, it was estimated that VO stayed, on average, 11.33 months in the warehouse. The warehouse costs $5,084.75/month and the total monthly staff salary added up to $2,110.86.
  - The storage costs were therefore estimated, for each packaging technology, using the following formula: Total storage cost per MT = ($5,084.75 + $2,110.86)* 11.33 months/capacity of warehouse in MT.
- Total cost (line 35): The total cost is the sum of the cost of bulk VO, operations, primary and secondary packaging, international freight, inland transport and storage. These can be added in cases where the user knows the cost of transport to the port and prepositioning.
- Yearly cost (line 36): The yearly cost is the estimated total spent on VO in one year if it was packaged in each packaging option, based on the total volume of VO procured for Title II programs in FY 2017 (84,092 MT)
- Cost difference vs. control (line 37): The cost difference vs. the control is the yearly difference in cost (based on volumes procured in FY 2017) if VO was packaged in the new packaging options considered instead of the control.

A sensitivity analysis is then automatically conducted to calculate what the price of the primary packaging would need to be for the cost difference to be $0.

VII.b. Protocol for Testing VO Packaging Options

Table 19: Detailed performance testing protocol

Test	Equipment	Samples
Package Climatic Conditioning Test +45°C, 85% RH for 72 Hours	Class 6 Chamber	3 boxes of filled cans/bottles per packaging type (18 total)
Packaging Vibration Test – 2 hours Random vibration testing per MIL-STD-810G w/change 1, Method 514.7 Figure 514.7D-9 - Shipboard Secured cargo (packages will be secured to table with crossbar[s]) Frequency band: 1 to 100 Hz Intensity: 0.315 Grms *Leaking cans/bottles will be removed from testing as soon as noticed. Unaltered cans/bottles will be consolidated so full boxes move on to the next test.*	Hydraulic Vibration Table	Same as above, base down
Package Loose Load Vibration Test – 180 minutes, equivalent to 1,350 miles traveled Loose Cargo Transportation per MIL-STD-810G w/change 1, Method 514.7 Procedure II, Figure 514.7C-5 Frequency band: 5 Hz Intensity: 1-inch, rotary motion	ED Vibration Table	Same as above, base down

Leaking cans/bottles will be removed from testing as soon as noticed. Unaltered cans/bottles will be consolidated so full boxes move on to the next test.		
Package Freefall Drop Test Per MIL-STD-810G w/change 1 516.7 Method IV: Partial Sequence 5 drops on 2" plywood backed by unyielding surface Orientations: - Box: Base, Side, Corner, Edge, Top - Can: Base, Side, Bottom Edge, Top Edge, Top Drop height: 48" *Testing will stop after leaks are noticed.*	Packaging laboratory	1 full box and 1 individual can/bottle per configuration (taken from those that have undergone vibration testing, above)
Package Climatic Conditioning Test +45°C, 85% RH for 72 Hours	Class 6 Chamber	3 boxes of empty cans/bottles per configuration (18 total)
Package Compression Test Compression test to failure per ASTM D642-15. Testing to be performed as soon as possible upon removal from climatic conditioning. Samples will be removed in batches to limit exposure to ambient conditions prior to testing.	Packaging laboratory	Same as above, base down

VII.c. Functionalities to Consider at All Steps of the Food Aid Supply Chain

Table 20 lists the key functionalities at every step of the supply chain, including those overlapping with costs or performance considerations.

Table 20: Desired functionalities of packaging system at each step of food aid supply chain

Level of Supply Chain	Functionality	Advantage	Overlaps
Packaging supplier	Standard packaging type/design	Reduces lead time and facilitates procurement. Multiple suppliers with the capacity to supply all the oil vendors.	Cost of packaging
Oil vendor	Adapted to the suppliers' equipment	Does not require heavy investments or changes to their current production line.	Cost of operation
Ocean transport	Optimizes handling by port and transport staff	Can be moved efficiently, thus saving time.	Transportation costs
Storage	Enables handling by warehouse workers	Can be moved efficiently, thus saving time and decreasing risk of damage.	- [13]
	Optimizes space occupation	Reduces size constraint when looking for warehouses in-country. Facilitates warehouse operations and circulation.	Storage costs
Inland transport	Optimizes inland transport (space occupation)	Reduces constraints when searching for transport options, which are not always the best.	Transportation costs
Distribution and beyond	Facilitates distribution to recipients (i.e. pouring, sharing, etc.)	Reduces time. Decreases food safety concerns.	-
	Facilitate handling and use by the recipients	Improves recipients' experience. Decreases food safety concerns.	-
	Allows for repurposing	Creates resources.	-
	Recyclable	Reduces waste generation.	-
Overall considerations	Does not lead to issues which could alter the image or reputation of the donor or the implementing partner	Maintains the food quality. Preserves the reputation and image of the donor and implementing partner.	Performance
	Overall environmental impact	The packaging technology used minimizes the overall environmental impact of food aid packaging (including packaging manufacturing, transport optimization, end-of-life waste generation, etc.)	-

[13] The ease of handling may slightly affect labor at the warehouse level but, for the purpose of this analysis, the cost of warehousing was a flat rate adjusted for space occupation only.

VII.d. Cost-offsets Calculations

The amount of losses which need to be prevented in order to make up for the cost difference due to the new packaging option is calculated using the following formula:

$$Losses\ to\ be\ prevented\ \left(\frac{MT}{FY}\right) = \frac{Cost\ difference\ (US\$/FY)}{Total\ cost\ (US\$/MT)}$$

The amount of reconditioning which needs to be prevented is calculated using the below formula. The cost of reconditioning was estimated to be about $331/MT, based on information obtained from Ethiopia and Burkina Faso.

$$Reconditioning\ to\ be\ prevented\ \left(\frac{MT}{FY}\right) = \frac{Cost\ difference\ (US\$/FY)}{331\ (US\$/MT)}$$

VII.e. Contribution of Each Cost Component to Total Costs for Each Packaging Option

Table 21: Contribution of each cost component to the total cost*

	Control	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Food product	43.04%	41.29%	43.34%	42.42%	41.99%	42.23%	45.05%
Primary packaging	15.82%	17.99%	15.20%	18.02%	17.48%	22.69%	7.90%
Secondary packaging	2.64%	2.59%	2.98%	2.45%	2.48%	2.07%	3.17%
Operations	11.69%	11.22%	11.77%	11.53%	11.41%	11.48%	12.24%
International transp.	21.73%	21.93%	21.61%	20.97%	21.77%	17.63%	25.96%
Inland transp.	3.61%	3.66%	3.59%	3.39%	3.61%	2.86%	4.07%
Storage	1.47%	1.31%	1.51%	1.24%	1.26%	1.05%	1.60%

* Option 1: Round can 1 + plug 1; Option 2: Round can 2 + plug 2; Option 3: Round can 3 + no plug; Option 4: Round can 4 + plug 1; Option 5: Rectangular can + pull-out spout; Option 6: PET bottle.

VII.f. Additional Test Results

The suppliers of Option 1 and 4 supplied samples with both their current plugs and a pullout spout purchased from a closure manufacturer (the same pullout spouts which were used for Option 5). Option 5 is meant to be used with a pullout spout (see Table 1) but testing was also conducted on Option 5 with a regular plug. The results of the vibration and drop tests performed on these samples are summarized on Table 22 and Table 23, respectively.

Table 22: Additional results–vibration testing

	Vibration testing – Ocean transport	Vibration testing – Road transport (loose load)	
		Time (min) until observation for each box	*Observation*
Option 1 + pullout spout	No leakage observed	No leakage observed	
Option 4 + pullout spout	No leakage observed	39, 39, 39	Leaking of 2 cans at body (box 1) Leaking of 1 can at body (boxes 2 and 3)
Option 5 + plug 1	No leakage observed	64, 105, 136	Leaking of 1 can at body (for all 3 boxes)

Table 23: Additional results–drop testing

	Time noticed	Observation
Option 1 + pullout spout–box	After corner (3rd) drop	One can had the plug come out
Option 1 + pullout spout–can	n/a	No leak observed
Option 4 + pullout spout–box	After top (5th) drop	One can leaked along the top seam/body
Option 4 + pullout spout–can	After side (2nd) drop	Damage to body (Another can was tested and the plug came out after the 4th [top edge] drop)
Option 5 + regular plug–box	After side (2nd) drop	Leakage around the plug
Option 5 + regular plug–can	n/a	No leak observed

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