



# Identifying and evaluating farmer deviations from steps recommended for hermetic postharvest storage of beans in northern Mozambique

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## ABSTRACT

Despite the fact of calls for studies to identify and assess the effects of user deviations from recommended innovation-practices disseminated to farmers in developing-nation contexts, such research remains rare. This study answers that call by drawing on prior research—which two years earlier had trained farmers in northern Mozambique in an 8-step, improved postharvest bean storage protocol using jerrycans—to investigate deviations (“reinventions”) by users from that protocol’s recommended practices. Results from this study found that while 91.3% of participants had used the storage innovation method at least once (high adoption), nearly half (45%) had deviated in at least one way from the eight recommended steps, with none (0%) reporting any failure of the innovation. Deviations consisted of two major types: skipping at least one of the eight steps (approximately 1 in 3 participants) and adding a step or element to the method (approximately 1 in 5 participants). These combined findings of high adoption, reinvention, and storage method effectiveness provide innovation designers and suppliers insights into the potentially crucial role of reinvention for successfully diffusing stored product innovations in developing nation contexts. The importance of further research into a means for assessing when reinvention has positive, neutral, or negative impacts on innovation goals is also discussed.

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## 1. Introduction

The current research explored an evaluation methodology for identifying protocol deviations from an eight-step method for hermetically storing beans among farmers in northern Mozambique and then assessing whether those deviations (as “reinventions”) had beneficial, neutral, or harmful impacts on the innovation’s intended goals. Once such deviations are identified and assessed, reasons why they occur can be studied, and scientific evaluations can be made concerning protocol adjustments (if needed) to ensure more exact matching of the postharvest storage innovation’s goals and actual outcomes. While deviations from recommended practices during postharvest bean storage may occur immediately after projects have trained farmers, they may

also evolve as farmers “reinvent” the practice to suit their individual circumstances. Although such deviations might be regarded negatively by those who created and tested the innovation, they might also help to increase the acceptability, if not also the effectiveness, of an innovation in some cases. As such, to develop a means for assessing whether reinventions have beneficial, neutral, or harmful effects on innovation implementations is essential for helping project goals to align with project outcomes.

Additionally, there has also been an emphasis in recent decades for making projects more participatory by including farmers at every step of the innovation process and carefully considering their access, ability, and willingness to utilize recommended practices or innovations (Chambers, 1983; Cleaver, 2001; Glenzer et al., 2011; Mulema and Mazur, 2016). While such participatory approaches can enhance adoption rates and may provide insights and changes useful to innovation researchers, designers, and scientists, they also increase the amount of deviation from recommended practices.

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### 1.1. The problem of deviation from recommended practices

Hermetic postharvest storage of common beans, *Phaseolus vulgaris* (L), can dramatically reduce damage caused by bean bruchids, *Acanthoscelides obtectus* (Say), and other insects that otherwise destroy 20% or more of the stored crop in many countries (García-Perea et al., 2014; Murdock and Baoua, 2014). When cleaned and dried correctly, storing beans or cowpeas in triple bags or sealed plastic containers reduces insect damage by cutting off oxygen needed by the insects, curtailing their activity, and resulting in their death or inactivity without the use of chemicals (Murdock et al., 2012). Freitas et al. (2016) found that bruchid populations in control bags increased 54% over 120 days, while those in triple bags or sealed plastic containers remained constant.

The use of triple bagging—e.g., Purdue Improved Cowpea Storage (PICS), GrainPro's Grainsafe, and Super Grain or similar technologies—is appropriate where 50 kg or 100 kg of beans or other grains need to be stored and where the bags are readily available at an affordable price (Walker et al., 2018). Smaller plastic containers hold fewer beans but are often more readily available locally and recyclable from other uses (Yakubu et al., 2016). The 80% of African farmers who store beans needed for seed, or those who harvest and store small amounts of beans, find plastic containers an excellent alternative (Murdock et al., 2012; Williams et al., 2016, 2017).

Despite this proven effectiveness for postharvest hermetic sealing of beans and other grains, an extensive body of social science research also demonstrates that farmers often refuse to adopt these new practices or will deviate from the recommended practices in some important ways when adopting (Rogers, 2003). In the following, then, this study examines two of the most frequent examples of such deviations: failure to follow recommended practices and the addition of steps that were not originally part of the recommended practices.

**Failure to follow all recommended steps of the adoption process.** Failure to follow all recommended steps can occur because farmers did not understand all of the steps, lacked some equipment or material needed, or for some reason based on previous experience or concerns. Rogers (2003) refers to the process of adapting or changing an innovation as “reinvention.” Diffusion research now acknowledges that reinvention commonly occurs, yet specific procedures for how to evaluate these deviations are seldom made explicit. Innovation recommendations developed outside of a recipient community or through a “top-down” approach often include specific doses, amounts, or procedures. When any of these specifications are not exactly followed, researchers can tally such adoption as a failure (Nadel et al., 2010).

Failure to follow every recommendation as specified, however, might still result in at least some benefit. For example, if a farmer uses only half as much fertilizer as was recommended, should this be considered a successful adoption or a failure (particularly if the crop yield was not significantly impacted by the lower dosage)? Recommendations will often involve ranges of values identified in various studies because, rather than trying to explain complicated ranges that depend on varying situations, the recommenders instead select specific average values. Moreover, when evaluating whether something constitutes successful adoption or a failure, it is vital to understand how much deviation can be tolerated. Frequently, whether a deviation results in failure or success can only be determined by examining that particular farmer's outcome. In other cases, laboratory or other field studies may provide the answer. To successfully evaluate the phenomenon of reinvention, then, one must first identify deviations that occur and then assess if such deviations positively, neutrally, or negatively affect the desired impact of the innovation. This situation makes it possible that, although an original innovation goal might not have been achieved,

some other secondary goal or purpose could have been served.

**Farmers follow all steps of the adoption process, but also include additional steps or processes that were not part of the original recommendation.** This may occur because farmers continue (“integrate”) a traditional practice they were using before the innovation. In these cases, farmers may not realize there is no longer any need to continue including these steps, or they may believe that the steps might still be needed even though they are also following all the new steps. Kiros-Meles and Abang (2008), for example, found that farmers in Ethiopia followed the recommended steps for an innovation for chickpeas but also applied kerosene oil to the seeds before planting, a practice they had used before with other seeds. Researchers had not studied whether or not adding kerosene would enhance or decrease the effectiveness of the recommended practice.

Classic diffusion of innovation efforts have often been evaluated using a single survey to measure how many recipients adopted the innovation. German et al. (2006) offers an important critique of this practice, along with constructive suggestions for how evaluations could be better conducted. They argue that a one-shot survey focused on the adoption of initially recommended practices fails “to capture re-invention processes taking place after introduction” (p. 355). Moreover, they argue that a constructivist approach that takes into account the multiple perceptions, interests, and actions of adopters is needed to minimize the “individual blame” bias (Rogers, 2003) often ascribed to any failure to follow all steps in top-down recommendations.

German et al. (2006) used focus group discussions with diverse farmer groups to identify reinventions, rejections, and reasons for farmer behaviors. On-farm household interviews were conducted to better understand and quantify what was happening and why. Interest focused not only on the initial innovation, but also on each step of the recommended practices, and any reinventions and rejections of those practices along with their rationales. The authors recommended additional focus groups to “ground truth” findings from individual interviews. The resulting evaluation is thus more comprehensive and examines not only the original innovation but also the modifications and reinventions that occurred. The authors note that additional research may be needed in some cases to evaluate the value of modifications and reinventions to the overall goals of farmers.

The purpose of this study echoes German et al. (2006) not only in its aim to explore an evaluation methodology for identifying beneficial, neutral, or harmful reinventions of a recommended practice by farmers but also in its implication that reinvention may be necessary (not just inevitable) for successful project outcomes. While this possibility directly challenges a prevailing tendency to frame reinvention as noise or an indication of failure (Kee, 2017; Nadel et al., 2010), to see how this is so requires a deep dive into the phenomenon that reinvention names. The apparent digression of this, then, yields insights that ultimately can help project designers, innovators, and research scientists to better align innovation goals with implementation outcomes.

### 1.2. Reinvention of innovations: modifying recommended steps

The concept of reinvention arose out of extensive research into what has been termed the “diffusion of innovations,” the process by which new ideas and practices move through a social system over time (Rogers, 2003). Like any emergent concept and term in a field, reinvention traces back to multiple prior sources (c.f., Berman and McLaughlin, 1974; Larsen and Agarwala-Rogers, 1977; Rogers, 1977) but received its now most familiar, current sense in Rice and Rogers (1980). Rogers (2003) has since defined “reinvention” as “the degree to which an innovation is changed or modified by a user in the

process of its adoption and implementation" (Rogers, 2003).

Reinvention in diffusion studies has often been treated as noise (Kee, 2017). Rogers (1975) long ago critiqued this view as betraying a pro-innovation bias too predisposed to frame any variant of exact adoption as a non-success or a problem. Indeed, even the type of adoption favorably observed around the same time by Von Hippel (1976) aligns completely with Rogers' description of early adopters who customize an innovation to suit their situation and needs and thus arguably represents an instance of reinvention. Moreover, this type of customization, as a reinvention, has since been shown to help make wider, subsequent community adoption more likely and occur more quickly (Hays, 1996; Majchrzak et al., 2000; Westphal et al., 1997).

Reinvention presupposes at least some level of adoption. Rice and Rogers (1980) identified several conditions likely to prompt reinvention, including the complexity of the innovation, the role and (in)effectiveness of innovation knowledge delivery, the failure of an innovation to adequately match adopters' actual local problems or their desire for local cultural self-expression, external exigencies related to "politics" or limited resources, or simply as an outcome of the innovation's use over time. Schmidt et al. (1997) paraphrased and refined these factors specifically for agricultural contexts as (1) the degree of local people's involvement in identifying the innovation needed and its possible solutions [applicability], also echoing (Freire, 1970); (2) the level of perceived need for the innovation by local farmers [relative advantage, relevance]; (3) the extent to which the solution proposed is readily available and affordable [compatibility, feasibility]; (4) the efficacy of the innovation in actually resolving a perceived problem [effectiveness, observability, and trialability]; and (5) the opportunity to receive information about the innovation in one's most comfortably spoken language using an effective delivery channel [accessibility]. These factors particularly afford a participatory, rather than "top-down," approach to solution research, creation, and deployment.

Given that reinvention has been shown as a regular occurrence in the adoption process and might be expected—especially in cases where participation and initiative by local farmers are encouraged—some means for accounting for these deviations in an evaluation process is needed. As such, Eveland's (1979) question, "If people define the innovation differently, and create new elements for it during the innovation process, to what degree do they meaningfully 'adopt' the same thing?" (p. 11) remains pertinent and largely unanswered. Eveland (1977) had earlier offered one possible approach: by breaking down each innovation into constituent elements and then examining each element for reinvention. However, the challenge of evaluating reinventions involves not only that we can detect them, but also whether we can determine if a given reinvention has a positive, neutral, or negative impact on the desired outcome of the innovation itself.

The fact that innovations are often introduced from outside the local culture—or that the setting or criteria for their evaluation come from outside the culture even though local input might have changed the innovation in some way—can lead to a failure to identify or value reinventions that occur in the diffusion process. Often, outside entities intend homogenous changes that can readily be evaluated by standard criteria and methods. Mason (2003) specifically criticized any insistence that all steps of an innovation must be followed exactly—not because any deviation would necessarily make the innovation fail, but because those who created the innovation also set the evaluation criteria for judging those deviations as failures.

### 1.3. Modifying innovations by adding additional steps

A special case of reinvention occurs when all the recommended steps for adoption of the innovation are followed generally as specified, but other actions also are taken beyond what is recommended. These additional actions may or may not affect the desired outcome of the innovation. One example of such addition is behavioral inertia. That is, prior to the introduction of the innovation, farmers have followed various traditional procedures—for example, they might choose to plant their seeds only when the moon is in its waxing phase. An introduction of row planting, rather than just scattering seed, would change the prevailing planting technique. However, farmers who adopt row planting might still follow the tradition of continuing to plant only when the moon is waxing. This is an additional action that, in this case, might not just limit planting date flexibility but probably would not have a significant impact on row planting. Research to assess if such a change would be helpful, harmful, or have no effect is vital so that researchers can understand any impacts. If the practice actually helps, it can be incorporated into future recommendations. If it has harmful effects, farmers need to be warned about such adverse effects to prevent its inertia. If it has neutral or no effects, evaluation procedures do not need to count this additional step as a failure.

Moreover, such additional actions taken by farmers are often missed or not identified in follow-ups because evaluations only confirm whether or not each recommended step was followed; the evaluation may include no method to ask about additional steps taken. Farmers might also take these additional steps for granted and not realize they would be important to mention. Unless one observes the carrying out of each step, or asks the farmer to walk through exactly what was done during the whole process, extra steps might never be identified, much less evaluated.

## 2. Materials and methods

### 2.1. Initial jerrycan storage method test

The previous research on which this article is based was part of an evaluation conducted into recommended practices for hermetic postharvest storage of bean seed in plastic jerrycans in ten Mozambique bean farming communities (five each in Tetete and Mepuagiu regions of Gurù District in northern Mozambique). Pre-project needs assessments and focus groups with local farmers had identified a need for quality bean seed in light of bruchid insect attacks and substantial damage on stored beans. Because the stored beans were primarily used as seed for the next season's planting (as well as less often for family meals or minor supplemental income) and were typically stored in the same rooms where family members lived, a safe non-chemical method was needed for postharvest storage.

A pre-test survey of 314 farmers showed that two-thirds had never heard about storing beans in plastic containers, that another one-quarter had heard about the method but knew no specific details about how to do it, and that 6.7% had used the method at least once previously. Most farmers stored beans in jute bags that were not tightly sealed, and most reported bruchid damage. A few farmers were using chemicals to protect their beans, and some of the chemicals were found to be hazardous to humans. Other farmers added ash or hot chili pepper to their beans when storing them in traditional jute bags to protect the beans. Most farmers already owned plastic jerrycan containers that were often used to haul and store water.

Project researchers, in collaboration with Scientific Animations Without Borders (SAWBO), developed an animated video

("Postharvest Loss: Jerrycan Bean Storage") that explained each of the eight steps for hermetically storing beans in jerrycans. This animation was then translated into the most comfortably spoken local dialect of Lomwé (SAWBO, 2015) for presentation to farmers, and extension agents in the area were trained on how to teach farmers each of the steps.

One of the most immediate ways to connect to the lived reality of rural people is through the use of their most comfortably spoken dialect, which can offer differ from urban dialects (Bello-Bravo and Pittendrigh, 2018; Chaiklin, 2003; Kiramba, 2018). Digital information and communication technology (ICT) delivery systems, such as animated video, have been used to complement or serve in place of extension workers (Asenso-Okyere and Mekonnen, 2012; Bello-Bravo et al., 2015, 2018; Bentley et al., 2015; Sseguya et al., 2012; Van Mele, 2011). In Mozambique, animated videos can help compensate for a severe shortfall of agricultural extension agents despite the country's commitment to agriculture and recent successes in conservation farming (Gemo and Rivera, 2001; Mango et al., 2017).

In June 2015, Mocumbe (2016) showed 314 farmers in small groups either the video animation itself, an extension in-person training on the jerrycan hermetic postharvest storage method, or a combination of these two approaches. Individuals in each group were then asked to demonstrate each of the eight steps using the jerrycan storage method in front of others, filling and sealing a plastic jerrycan. A second jerrycan also was filled but was sealed with a mesh that would admit oxygen but not permit bruchids to enter or leave. Both containers were then entrusted to a local farmer to guard for six months. Immediately following the training, farmers received a post-test to assess their knowledge of the eight steps. Results showed that farmers scored an average of 91.3% correct on knowledge of the eight recommended steps. At the end of the six months, the farmers again gathered and opened both containers in each village. Results demonstrated that beans in the properly sealed plastic jerrycans were in excellent condition, while beans in the mesh-topped jerrycans had suffered significant bruchid damage.

## 2.2. Follow-up study of deviations

Two years later, in June 2017, interviews were conducted with as many of the original participants as possible, equaling 104 of the original 314 in six of the ten original villages. Specifically, in Tetete's three villages, 66 farmers were interviewed in 2015, and 44 (66.6%) were located and re-interviewed in 2017. In Mepuagiu, 115 farmers in the three selected villages were interviewed in 2015, and 60 (52.1%) were located and re-interviewed in 2017. This follow-up interview used the same procedure as the prior research to ask if farmers remembered the postharvest storage method and what its eight steps were. As was the case in 2015, if a farmer failed to mention a step, a reminder probe was used, such as "Was there anything else that needed to be done before the beans were placed in the container?" Those who then remembered the correct information were counted as providing correct answers.

## 2.3. Data analysis

Two samples *t*-test were applied to the 2015 vs. 2017 survey results for every knowledge test item, with a one sample *t*-test applied to the questions: "Did you open the lid during the storage time?" and "Added zinza ash or piri-piri chili pepper to their beans?" Statpac software was used for these tests.

## 3. Results

### 3.1. Use of jerrycan hermetic storage method and frequency of deviations

Table 1 compares the percentage of correct answers given in 2015 to that in 2017. Results showed that interviewed farmers overall had higher scores in 2017, with 97.9% of participants able to repeat the correct recommendations. For each question, the number of correct answers from 2015 to 2017 either increased or remained the same (see Table 1).

Results also showed that 91.3% (95 out of the 104) farmers re-interviewed in 2017 had used the postharvest jerrycan storage method at least once. This 91.3% adoption rate represents a highly successful innovation introduction given that most innovations fall far short of this percentage. While this innovation clearly addressed a need that farmers had for more secure postharvest bean storage, the high adoption rate also provided an opportunity to explore how farmers might have deviated from the eight steps. For this reason, several additional questions were asked to probe deviations in their use of the method. For example, one question asked farmers, "Did you unseal and open the lid of the plastic container during the storage time?" They had been told to leave the container tightly sealed until they needed the beans. A second question asked if they added anything to the beans at the time when they were sealed. The recommendation for this step did not include any additions, but researchers had learned that traditionally farmers did add zinza ash or piri-piri chili pepper to their beans to protect them.

Because this was an exploratory study, no effort was made to identify all possible deviations that might have occurred. However, any comments made by farmers indicating that they did something other than the eight recommended steps prompted follow-up questions by researchers to determine what was done and why.

In response to the first question—whether or not they unsealed the container prior to when the beans were used—Table 2 shows that 33 (34.7%) of the 95 farmers who adopted the technique also said they opened the lid at least once during the time it was supposed to be sealed. Thus, significantly more farmers opted not to open the lid as instructed in the video compared to those who opened the lid [Table 2;  $t(104) = 3.268, p < 0.01$ ]. Most said they only opened the container once to quickly check to see if the beans were okay and then resealed it tightly. In response to the second question—whether farmers added anything to the stored beans—Table 3 shows that 18 (18.9%) of the 95 farmers added either zinza ash or piri-piri pepper or both to the beans, introducing something that might have affected the quality of the postharvest storage process. Thus, significantly more farmers opted not to add anything as compared to those who added either zinza ash or piri-piri chili pepper or both to the beans [Table 3;  $t(103) = 7.081, p < 0.01$ ]. Collectively, the 33 who opened their containers early also included 8 who added ash or chili pepper to their beans. That means 10 of the 18 who added ash or chili pepper did not open their containers early.

In total, 43 of the 95 adopters (45.3%) took at least one of the two actions that deviated from what was recommended. The fact that almost half of the farmers deviated in at least one way from what was recommended provides strong evidence that evaluations need to identify and examine these deviations to determine what effect they might have had on the effectiveness of the jerrycan postharvest storage innovation. Consequently, an examination of each of the deviations was conducted to help identify what farmers did, why they did it, and what type of evaluation might be needed to determine impacts that occurred.

Each of these two deviations will now be examined in more detail. The first—not following the step to keep the lid tightly



**Table 1**

Post-test 8-item knowledge test results in 2015 and 2017 Re-Test.

Knowledge Test Aspect	Post-Test % Correct		t-test	
	2015 (n = 314)	2017 (n = 104)	df = 416	p value
Dry the beans very well before putting in the can	93.0	100	2.772	.0058
Remove pebbles and broken beans	91.1	99.0	2.749	.0062
Ensure the jerrycan is clean and dry	85.0	97.1	3.292	.0011
Fill the jerrycan completely with beans, shaking it to ensure there is no space to circulate air inside	96.5	94.1	1.112	.2670
Use an additional piece of plastic by placing it under the jerrycan cap to ensure it is securely sealed so that oxygen cannot enter the jerrycan	90.9	99.0	2.79	.0055
Once sealed, do not open the jerrycan until ready to use	90.1	97.1	2.260	.0243
Beans can be stored in the jerrycan for up to six months and then used as seed for sowing	92.3	96.9	1.643	.1012
For food, the beans can be retained longer, up to several years.	91.7	100	3.034	.0026
Average Correct (Overall)	91.3	97.9	2.278	.0233

Source: 2015 results are from [Mocumbe \(2016\)](#).**Table 2**

Responses to the question "Did you open the lid during the storage time?".

	Count	Percent	Valid Percent	t-test open vs sealed (58.9 + 6.3)	df = 103
Yes, I opened the lid during the storage time	33	31.7	34.7	3.268	.0015
Lid remained sealed for the whole period	56	53.8	58.9		
Lid is still sealed; never opened container	6	5.8	6.3		
Total	95	91.3	100.0		
Did not use the method	9	8.7			
Total	104	100.0			

**Table 3**

Percentage of farmers who added zinza ash, piri-piri chili pepper, or both to stored beans.

	Count	Percent	Valid Percent	t-test p value (added vs not added)
Added zinza ash	14	13.4	14.7	.0000
Added piri-piri chili pepper	1	1.0	1.1	
Added both zinza ash and piri-piri chili pepper	3	2.9	3.2	
Did not add anything	71	68.3	74.7	
No response to this question	6	5.8	6.3	
Total	95	91.3	100.0	
Did not use method	9	8.7		
Total	104	100.0		

sealed until ready for use—is clearly a deviation from recommended practice. The second—adding ash or chili pepper to the dried and cleaned beans—represents an example of an additional action taken by farmers beyond what was recommended.

### 3.2. Deviation 1: opening the sealed container at least once to check beans

Nearly all of the farmers (97.1%) remembered the step "once sealed, do not open the jerrycan until ready to use." Nonetheless, 34.7% of farmers who stored their beans in a jerrycan reported re-inventing the innovation by opening the lid at least once. There was little difference between men and women, with 32.8% of the men opening their containers and 38.2% of the women. The researchers' rationale for this step is that opening the lid after sealing permits oxygen to re-enter the jerrycan and potentially enlivens dormant bruchids or allows bruchid larvae to hatch. When asked why they opened the lid, a majority responded that they wanted to check that there had been no bruchid activity and no damage to the beans.

Farmers who opened the jerrycan most often did so approximately 30 days after initial sealing. Finding no damage, they then re-sealed the lid and did not open it again until used for planting. One farmer reported removing the beans entirely, re-drying, and

then replacing them. Although opening the lid exposed the stored beans to potential bruchid hatching and damage, all farmers nonetheless reported that when they opened their jerrycans at planting time, they found the beans still in excellent condition and with no holes or insect infestation.

### 3.3. Deviation 2: additional step of adding ash or hot chili pepper

In broad terms, the second deviation of adding ash or hot chili pepper before storing beans was due to behavioral inertia ([Ching et al., 2017](#)), the tendency to continue practices that were used before when adopting a new practice. Pre-project interviews identified adding ash or chili pepper as common among farmers prior to the innovation, but it was largely assumed by researchers that hermetic sealing would replace these practices. In fact, the video animation and extension training emphasized the need to "remove pebbles and broken beans" as well as foreign material, but it did not specifically address the idea of discontinuing the use of ash or chili pepper. On the 2015 knowledge test, 91.1% of farmers correctly recalled this step; in 2017, 99% of farmers correctly recalled this step.

The 2017 survey showed that 18.9% of farmers (18 of the 95 who tried the jerrycan postharvest storage method) continued to add

either zinza ash or piri-iri chili pepper or both. Sixteen of the 18 were men; women were significantly less likely to add anything to beans (See Table 4). More than 27% of men added either zinza ash or piri-iri chili pepper, compared to only 6.5% of women.

The practice of adding ash, sand, or chili pepper to beans has been a traditional practice for a very long time. [Murdock and Baoua \(2014\)](#) documented use of ash for cowpea grain in the early 1990s. [Baoua et al. \(2012\)](#) confirmed that adding wood ash significantly reduced bruchid damage in cowpeas. Thus, farmers who continued adding ash were likely doing so based on their long-standing experiences.

Pro-innovation bias often focuses on the adoption of new methods and discontinuance of old methods rather than the possibility of using them jointly. The present case shows that a traditional or alternative research-based practice might be combined with the hermetic sealing of beans. This is a form of continuance, rather than discontinuance, and represents a synthesis of method rather than a choice between one or the other. Evaluatively, in terms of livelihood or social impacts, this reinvention may have helped to “fit” in the innovation into existing agricultural practices locally.

#### 4. Discussion

The purpose of this study was to explore deviations that occur in the diffusion of innovations process and to develop improved evaluation methods for taking them into account. The study builds on the recommendations of [German et al. \(2006\)](#), who advocate for assessing the value (or effect) of deviations on achieving innovation goals. The main findings of this study are that (1) deviations are common, and (2) in the present case appear to have been non-harmful, as discussed below.

##### 4.1. Deviations from recommended postharvest steps are common

Our study confirmed that deviations are common. For the introduction of a jerrycan postharvest method to hermetically store beans in Mozambique, examination of two deviations identified in the study measured nearly half (45%) of farmers had deviated from the recommended innovation steps in at least one way. Because the purpose of this study was exploratory, no attempt was made to document all of the possible deviations that might have occurred. Nonetheless, the fact that so many farmers deviated for just these two recommendations provides a strong indication that evaluation procedures would benefit from further assessing if such deviations have beneficial, neutral, or harmful impacts on innovation outcomes.

Deviations might be expected to be more numerous as projects increasingly adopt participatory approaches for the introduction of innovations. Participatory approaches involve farmers in problem diagnosis and include farmer input and participation in the process. While this increases the “buy-in” for innovations that are appropriate for the farmers, it also increases the possibility that farmers

will take ownership and act on their own ideas or perceptions about the innovation, including deviations from recommended practices or the addition of other practices that were not recommended.

One evaluation issue concerns whether or not a given farmer should be tallied as having “adopted” an innovation. In our study of the jerrycan storage method, 91.3% of farmers, or 95 out of 104, said they had tried the method and found that it was successful for preventing bruchid damage of their beans, a 0% innovation failure rate. Most reported using the method more than once, a strong indication of adoption. But does adoption mean that all recommended steps of the process have been followed exactly? One-third of the farmers reported breaking the hermetic seal on their jerrycan—usually after about 30 days—to see if the beans looked okay. They knew and were aware that doing this violated the strict training recommendation about not opening the container during the first several months, but they opened it nonetheless. And then they resealed the container immediately. Does this mean they are not truly adopters? Also, approximately one in five farmers – mostly men – followed the traditional practice of adding zinza ash or piri-iri chili pepper to their beans while otherwise following the recommended steps they learned in the training. Did adding this foreign material to the cleaned and dried beans mean that they did not truly “adopt” the innovation? Because funding for the introduction of innovations often comes from NGOs, governments, or other outside groups, having the highest possible numbers of adopters can serve as evidence to donors of a project’s or innovation’s efficacy. As such, even successful deviations (if viewed as non-adoption) might threaten this funding and be ignored (or simply missed) in evaluations.

##### 4.2. Beneficial, neutral, or harmful deviations

Regarding a skipped-step deviation (in this case, not following the recommendation not to open the container until the beans are to be used), previous research has found that briefly opening sealed containers or even small holes in the containers does not necessarily result in large increases in bruchid populations and damage ([Baoua et al., 2013](#)). Several potential factors, including bag size, moisture levels, temperature, and numbers of bruchids present will affect how quickly oxygen levels drop to a critical point that kills the bruchids. Once dead, opening the container would have minimal effects. One study of storage of common beans found that in as short a time as six days, oxygen levels dropped to levels that would make it safe to open the containers ([García-Perea et al., 2014](#)). However, other studies found that oxygen levels did not drop to safe levels for up to six weeks. If one knows the volume of the container (and assumes it is completely filled with beans) and the storage temperature, the length of time it will take for the bruchids to die can be calculated (Bern, personal communication, 2019). The fact that all farmers who opened their lids briefly found that their beans were still in excellent condition suggests that, in this case, 30 days was sufficient to kill the bruchids. Other studies have shown that even when holes in storage containers are present, the damage is minimal ([Williams et al., 2016](#)), or often confined to the area nearest the hole while oxygen levels deeper in the container remain low ([Martin et al., 2015](#)). [Murdock and Baoua \(2014\)](#) concluded that, while not recommended, the common practice of families dipping into their stored containers for a few beans for dinner might not be as damaging as predicted if the containers are quickly and adequately sealed again. [Baoua et al. \(2013\)](#) confirmed that farmers who opened their sealed cowpea containers occasionally still reported that the remaining beans sustained little bruchid damage.

It was fortunate in this case that despite deviating from the recommended practice to keep the lid tightly sealed, farmers

**Table 4**  
Percentage of men and women adding zinza ash or piri-iri chili pepper to sealed beans (n = 89\*).

	Added Something	Did Not Add Anything	Totals
Men	16 (27.6%)	42 (72.4%)	58 (100%)
Women	2 (6.5%)	29 (93.5%)	31 (100%)
Total	18 (20.2%)	71 (79.8%)	89

Chi-Square = 5.59,  $p = 0.014$ . \*Note: 6 of the 95 farmers who tried the jerrycan storage method did not indicate whether or not they added anything, so this table is based upon the remaining 89.

reported no significant increase in bruchid damage. However, it is clear from this example that there is a strong tendency by farmers to deviate from the recommended practice even though they know full well that they should not break the seal. Many might know the rule but still reason that a quick look or dipping into the bag to get some beans for dinner or sale would not harm the rest. They may not understand the dynamics of how fresh oxygen can revitalize the bruchid population. Additional material in the SAWBO training video should focus on this topic, and especially on risks in opening the containers too early in the process or too frequently. A specific example showing a 10 L sealed container filled with beans at a temperature common to the farmers' area could calculate how soon the farmer might be able to open the lid to inspect the previous seed beans or remove some beans out of a container for dinner. One other alternative might be to utilize 1.5 L clear plastic beverage containers or something larger and transparent such that the insides can be inspected without breaking the seal.

Regarding an added-element deviation (in this case, the addition of zinza ash, piri-piri chili pepper, or both), this addition did not seem to interfere with the effectiveness of the jerrycan storage technique for meeting its designed outcomes. Farmers who added the ash and chili pepper were just as likely as others to conclude that the jerrycan storage method protected their beans from bruchid damage. Research suggests that since adding the ash also protects against bruchids (the insects are repulsed by it, not killed), no reduction in the effectiveness of the jerrycan hermetic sealing should have occurred by adding ash (Baoua et al., 2012). There is some measure of risk that this augmentation may introduce an element into the storage system that could reduce the technique's effectiveness by introducing moisture. However, there is no immediate or scientific reason *a priori* to frame this addition as a sub-optimal behavior. Further research can confirm whether or not joint use of ash and hermetic sealing would be more, less, or equally effective.

Rogers (2003) notes that the adoption of innovations is more likely when they fit with existing practices. If adding ash or chili pepper increases solution uptake—for instance, by alleviating worries or concerns about the innovation—then the continuance of that local practice may play a potentially important role in securing the innovation's use (Eveland, 1979). More broadly, this continuity of local practice signals the ground on which a new method of bean storage in the Tetete and Mepuagiu regions becomes culturally intelligible and acceptable. In this sense, reinvention represents a translation of behavioral practice into a locally intelligible dialect that resonates with the kind of positive social impacts identified in German et al. (2006).

While it is not clear whether farmers who added chili pepper and ash will continue to do so in the future, the reinvention could be considered an integral part of any evaluation process of innovation delivery in the area. If the additions reduce the effectiveness of the storage method, then researchers may need to develop specialized training and communication messages to ensure that farmers do not use the additions or develop changes to the ash or chili pepper to neutralize the risks raised by their addition. If, on the contrary, this reinvention has at worst only neutral impacts, then this suggests they may be safely tolerated. And, alternatively, if such measures help to increase the innovation's effectiveness or adoption, this may prompt the incorporation of these local techniques into messages in subsequent trainings.

As a note on this pattern, however, while we measured a general parity between men (32.8%) and women (38.2%) for skipping a step, of the 18 participants who added ash, pepper, or both, 16 were men, and 2 were women. While it would be premature to speculate why this disparity occurred (if it is even significant), it may point to the ways that gendered differences can inform agricultural/

technological innovation adoption (Ilie et al., 2005; Ndiritu et al., 2014) and hint at reinvention variants that may be gendered as well. This is a matter for future research.

#### 4.3. Recommendations for future evaluations

Three recommendations are offered to help improve evaluation procedures, examine impacts of deviations, and improve subsequent training:

First, projects should routinely include plans and funding for identifying and studying deviations that occur to determine whether or not they are beneficial, neutral, or harmful. They also should include the possibility that while the deviation might have negative impacts on the initial innovation, it might have positive impacts that should be encouraged. Ideally, farmers should also be evaluated after several years of experience with hermetically sealing their beans in order to identify further reinventions that may have occurred.

Second, during initial pre-project interviews and focus groups with farmers, it is vital to thoroughly identify current practices used. In the present project, researchers learned that some farmers added ash and chili pepper to stored beans to control bruchids. A list of these practices should be assembled. During the post-test following training and adoption, farmers should be asked if they are still using any of the traditional methods instead of, or in addition to, the recommended steps.

Third, very often, communication materials such as video animations and instruction guides are developed early on in a project and used for training farmers about an innovation. However, these materials need to be amended or enhanced to include information that takes into account deviations that occur subsequently. There are several possibilities: (1) If the research conducted on deviations indicates that reinventions have a negative effect that is not offset by some other positive results, subsequent communication and training materials should be revised to specifically address the possible deviations and reasons why they should be avoided. (2) If the impacts of the deviations are found to be neutral, they might not be mentioned in future training. If including a traditional practice that is found to have no harm might make farmers more likely to adopt the recommended technology, it might be included in future training materials. (3) If the research indicates that the deviation is positive, it should be included in future training materials. If the research shows that the deviation provides a benefit that is important but different from that for which the original innovation was introduced, it should be captured so that farmers can continue to use it even if the original innovation is discarded.

The high frequency of deviations suggests viewing them not as noise but, rather, as an inherent and even necessary aspect of the adoption process. As Rogers (2003) observed, reinvention is “the degree to which an innovation is changed or modified by a user in the process of its adoption and implementation” (p. 180, emphasis added by authors). Strictly reasoned, no re-performance of a demonstration by a knowledgeable recipient could ever exactly and perfectly reproduce the demonstration. As such, an innovation is always changed or modified by a user, however slightly, in the process of its adoption and implementation. The question, then, cannot be whether reinvention happens or not but, instead, whether the degree of reinvention is such that it inhibits, enhances, or has no effect on the intended outcome of the innovation itself.

#### 4.4. Limitations

This study focuses on reinventions that occurred in one project that covered several geographic areas of Mozambique. Other projects focusing on different innovations in other countries would not

expect to find identical deviations. Similarly, while we cannot generalize from our single study data that deviations occur in all projects, other studies (German et al., 2006) have examined a number of different projects and confirmed that reinvention is common. The purpose of this study was not to demonstrate its universal commonness; instead, it was to examine two cases of deviation in some detail to capture lessons for future evaluators.

Deviations are not confined to a single moment or period in time. As farmers gain more experience with an innovation, or apply their creative minds to resolve problems they perceive, they will continually adapt (reinvent) the innovation to suit their needs. Thus, evaluation becomes a continuing concern. Ideally, periodic opportunities to revisit project innovations over time should occur for analyzing any deviations taking place, taking action to warn of negative results, and encouraging additions or changes to practice that yield positive outcomes. Later evaluations could help to measure: (1) the local evolution and any further reinvention of the recommended steps as the best-practices become more and more locally integrated; (2) the ultimate extent and use of the practice locally over many seasons, including the degree of commitment by local farmers to its future use; (3) the extent and diffusion of the practice beyond the current milieu; and (4) any inputs leading to improvements or modifications in the animated videos, extension training, or other materials.

#### Author statement

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#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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