

Assessment of *Jatropha curcas*-infused hermetic plastic bottles on maize grain in storage

Nathaniel Olu Alamuoye¹, Ernest Olaolu Dawodu², Ruth Oluwatobi Adetunji¹, Lawrence Kunle Otiotoju¹, Temitayo Funmi Falode²

¹ Department of Food Science and Technology, School of Agriculture and Agricultural Technology, Bamidele Olumilua University of Education Science and Technology, Ikere Ekiti, Nigeria

² Department of Agricultural Science and Technology, School of Agriculture and Agricultural Technology, Bamidele Olumilua University of Education Science and Technology, Ikere Ekiti, Nigeria

Abstract

This study investigates the efficacy of *Jatropha curcas*-infused hermetic plastic bottles as a storage medium for maize grains (*Zea mays*), with a focus on pest control, grain preservation, and seed viability. The research aimed to assess the impact of *Jatropha curcas* infusion on five key storage quality parameters which include the survival rate of *Sitophilus zeamais* (maize weevil), weight retention of stored maize grains, percentage moisture retention, fungal load, and germination percentage post-storage. Maize grains were stored for 180 days period in both *Jatropha curcas*-infused and non-infused hermetic plastic bottles under controlled conditions. Results showed a significant reduction (0%) in the survival rate of *S. zeamais* in the *J. curcas*-infused containers compared to the control (90%) at eleventh day of infestation, indicating a potent insecticidal effect. Weight loss was also markedly lower (0.5%) in the *J. curcas*-treated storage, correlating with reduced insect and fungal damage. Moisture retention levels remained within the range of 99.77 to 84.54% in both storage types, although more stabilized in *J. curcas*-infused containers. Fungal load analysis revealed too few to quantify colony-forming units in the *J. curcas*-treated bottles, suggesting antifungal properties of *J. curcas*. Finally, germination tests indicated a higher percentage of viable seeds from grains stored in the infused containers with only 10% reduction recorded after 180 days of storage, affirming the method's potential in preserving seed quality. These findings highlight *Jatropha curcas*-infused hermetic storage as a promising, natural alternative for maintaining maize grain integrity during storage, particularly in regions prone to post-harvest losses due to insect infestation and fungal contamination.

Keywords: *Sitophilus zeamais*, survival rate, fungal load, germination, moisture

Introduction

Agriculture holds substantial importance within numerous developing nation contexts, delivering essential food security and livelihoods to a multitude (Lucantoni and Domarle, 2023; Nzima *et al.*, 2024; Haile *et al.*, 2024) [1, 2, 3]. Pests, notably insects and rodents, cause considerable damage to stored grains via consumption or contamination (Stathas *et al.*, 2023; Khanam *et al.*, 2025) [4, 5]. In contrast, post-harvest losses from insect infestations present considerable hurdles for farmers, notably concerning maize storage (Samba *et al.*, 2022; Geremew *et al.*, 2023) [6, 7]. Mold proliferation may ensue from insect infestation, improper ventilation or elevated humidity, ensuing in mycotoxin contamination, which imparts health risks to both humans and animals (Brimblecombe *et al.*, 2022; Liu *et al.*, 2024) [8, 9]. A plethora of investigations have underscored the adverse consequences of fungal growth on stored maize grain, culminating in considerable economic detriments and adverse health effects (Odjo *et al.*, 2022; Brito *et al.*, 2022; De Lara Pires Batista Gomes *et al.*, 2024; Lu *et al.*, 2024) [10, 11, 12, 13]. Conventional modalities of maize preservation, such as chemical fumigation, have engendered apprehensions on account of potential health perils and ecological threats (Li *et al.*, 2024) [14]. Moisture accumulation, conversely, can encourage fungi and bacteria growth, further degrading the quality of the stored maize (Del Carmen García *et al.*, 2022; Daba *et al.*, 2024) [15, 16].

Also, earlier research works have indicated that maize seeds are prone to injury inflicted by insects, mold, and moisture during storage periods, which results in reduced germination rates (Khalid *et al.*, 2024; Odjo *et al.*, 2022) [17, 18]. Conventional storage techniques, such as the utilization of woven sacks or open containers, frequently fail to effectively mitigate these problems (Kuyu *et al.*, 2022; M and Khandai, 2024) [19, 20]. In an attempt to resolve this issue, hermetic storage solutions have been conceived to create a low-oxygen setting that suppresses pest and pathogen development. Hermetic bottles infused with *Jatropha* would probably demonstrate a promising outcome in maintaining the quality of stored maize by deterring insects and suppressing mold proliferation. However, scant research has been carried out to evaluate the germination rates of maize seeds kept in such containers.

A progressively noted, viable solution encompasses utilizing hermetic storage combined with botanical extracts, exemplified by *Jatropha curcas*, acknowledged for its insecticidal attributes. Although this technological approach appears advantageous, however, existing empirical evidence on its efficacy in mitigating insect infestations in stored maize grains remains sparse. This research aims to bridge this knowledge deficit by assessing the impacts of *Jatropha curcas*-infused hermetic plastic bottles on stored maize grain. Grasping the effectiveness of such an intervention holds substantial importance for fostering sustainable agricultural methodologies and augmenting food security

for smallholder farmers within developing sectors. The principal research objective is to assess the quality of the stored maize grain, focusing on moisture control, germination rates, fungal load, weight loss, survival rate of *Sitophilus zeamais* post-storage in these containers. By addressing these objectives, this study will provide pertinent insights to the domain of postharvest management and propose sustainable methods to bolster food security and diminish postharvest losses.

Materials and methods

1. Steps to production of *Jatropha curcas* powder

The research focused on use of *Jatropha curcas* seeds to produce a versatile powder. The process of obtaining powder from *Jatropha curcas* seeds used in this study, involved crushing the seeds without oil extraction, followed by drying and grinding to obtain a fine powder.

2. Experimental Procedure

To evaluate the impacts of *Jatropha curcas*-infused hermetic one-liter (1L) plastic bottles on stored maize grain, a strong methodology was used. A randomized controlled design was devised to study the efficacy of these hermetic plastic bottles against traditional storage method. The study had a sample of maize grains divided into two groups: one in *Jatropha curcas*-infused hermetic one-liter (1L) plastic bottles and the other in hermetic one-liter (1L) plastic bottles without *Jatropha curcas* treatment. 990 grams each of sterilized maize grains to ten grammes (10g) of *Jatropha curcas* powder were put hermetically in one-liter (1L) plastic bottles and another 1kg of sterilized maize were put hermetically in one-liter (1L) plastic bottles without *Jatropha curcas* powder treatment. Ten pair of *Sitophilus zeamais* were introduced separately into the two groups of plastic bottles before they were hermetically sealed. Proper labeling was done for easy identification and tracking of the samples stored in both hermetic plastic bottles. The experiment proceeded at laboratory temperatures (20 – 25 °C).

Observations were conducted regularly over a duration of six months to track the population dynamics of *Sitophilus zeamais* in the packaging bottles. Regular monitoring of grain weight, moisture content, fungal load and viability of the maize grain over six months at 30-day intervals were observed. Three replicates to each of the group and analysis per month were used to accommodate variations, minimize error and lend statistical significance to the findings.

3. Determination of the Survival rate of *Sitophilus zeamais* in *Jatropha curcas* and non-*Jatropha curcas* infused Hermetic Plastic Bottles

The survival rate was calculated after 72 hours as below:

$$\frac{\text{Total Number of Insect introduced} - \text{Number of dead insects}}{\text{Total number of insect introduced}} \times 100 \dots \text{Equation 1}$$

Alamuoye, 2019

4. Weight determination of maize grains stored in *Jatropha curcas* and non-*Jatropha curcas* infused Hermetic Plastic Bottles

In undertaking the examination regarding the weight determination of maize kernels preserved within containers infused with *Jatropha curcas* and non-*Jatropha curcas* powder, a methodical approach was adhered to, aimed at

ensuring the precision and dependability of the outcomes. Initially, the procedure entailed the precise measurement and documentation of each maize grain's weight prior to storage in the plastic bottles. Subsequently, the maize kernels were enclosed in the hermetic plastic bottles infused with or without *Jatropha curcas* powder for six months duration. Upon the culmination of the storage interval of one month, the grains were extracted from the containers, and weighed with triple balance to ascertain any weight variations (Alamuoye, 2019) [22]. This sequence was executed repeatedly to mitigate any inconsistencies in the results. Through this approach, the examination was able to precisely evaluate the impact of *Jatropha curcas* infusion, insect infestation and packaging materials on the weight of stored maize grains, contributing valuable knowledge regarding the potential uses of this preservation technique for agricultural produce.

$$\text{Weight loss \%} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100 \quad \text{Equation 2}$$

2.5 Percentage moisture retention determination of maize grains stored in *Jatropha curcas* and non-*Jatropha curcas* infused Hermetic Plastic Bottles

The method utilized for the determination of moisture retention percentage in maize subjected to storage within *Jatropha curcas*-infused hermetic bags and non-*Jatropha curcas* infused hermetic bottles encompassed a series of steps. Initially, the moisture content of the maize samples was determined before storage. Maize samples from various bottles were systematically collected at predetermined intervals and the moisture content determined adhering to a standard gravimetric approach, wherein samples were subjected to oven drying at 105 °C until a stable weight was attained. This precise procedure not only facilitated the attainment of accurate and reliable measurements but also enabled the detection of any potential fluctuations in moisture content over time as replications were employed.

$$\% \text{ MR} = \frac{\text{Final moisture}}{\text{Initial moisture}} \times 100 \quad \text{Equation 3}$$

% MR = % Moisture Retention

2.6 Fungal load determination of maize grains stored in *Jatropha curcas* and non-*Jatropha curcas* infused Hermetic Plastic Bottles

To accurately determine the fungal load in maize grains stored in *Jatropha curcas* and non-*Jatropha curcas* infused Hermetic Plastic Bottles, a rigorous methodology was employed. Initially, samples were collected from different batches of maize grains stored in both plastic bottles. The samples were carefully processed and plated on appropriate potato dextrose agar media for fungal growth. Incubation was done at 25° C for 72 hours (Hocking and Pitt, 2009) [23]. Following incubation, the colonies were counted using digital colony counter (Gallenkampy Colony Counter 5A044) and the fungal load was calculated per gram of maize grain (Muhammad *et al.*, 2016) [24].

$$\text{Fungal Load (CFU)} = \frac{\text{Number of colonies} \times \text{Dilution factor}}{\text{Volume of sample plated (mL)}} \quad \text{Equation 4}$$

2.7 Germination percentage assessment of maize grains stored in *Jatropha curcas* and non-*Jatropha curcas* infused Hermetic Plastic Bottles

Thirty seeds were removed from each of the groups in triplicate and placed in petri dishes containing filter paper dampened with distilled water and covered with perforated lids for regulated air exchange simulating realistic conditions. Regular watering intervals of six hours was used to simulate moisture accessibility in controlled environment. This very precise methodology made sure consistency in germination process and enable monitoring of key indicators, like root and shoot emergence, to trace seed viability. The number of germinated seeds was recorded and used to calculate the germination percentage for each type of storage container. This methodology allowed for a precise comparison of the germination rates between grains stored in *Jatropha curcas*-infused hermetic plastic bottles and non-*Jatropha curcas* infused hermetic plastic bottles.

$$\text{Germination Percentage} = \frac{\text{Number of Germinated Seeds}}{\text{Total Number of Seeds Tested}} \times 100$$

Equation 5

Statistical analysis methods

In this study, statistical analysis was executed employing IBM SPSS Statistics 20. This was done specifically using a One-way ANOVA Post Hoc Multiple Comparisons method, applying the Tukey's-b test at a significance level of 0.05. (IBM SPSS, 2011) [24]

Table1: Survivorship percentage of *Sitophilus zeamais* Survival rate of *Sitophilus zeamais* in *Jatropha curcas* and non-*Jatropha curcas* infused Hermetic Plastic Bottles

Days	Storage materials / % survivorship	
	<i>Jatropha curcas</i> -Infused Hermetic Plastic Bottle	Non- <i>Jatropha curcas</i> -Infused Hermetic Plastic Bottle
1	100 ± 0.000 ^a	100 ± 0.000 ^a
3	90 ± 5.774 ^a	100 ± 0.000 ^a
5	90 ± 5.774 ^a	100 ± 0.000 ^a
7	50 ± 5.774 ^b	100 ± 0.000 ^a
9	0 ± 0.000 ^c	100 ± 0.000 ^a
11	0 ± 0.000 ^c	90 ± 5.774 ^a

The results indicate the mean values of triplicate measurements ± standard error of the mean. Mean values within the same column that are denoted by the same letter do not show significant differences at $p \leq 0.05$.

Percentage reduction in weight of maize grains stored in *Jatropha curcas*-infused hermetic plastic bottles and non-*Jatropha curcas* infused hermetic plastic bottles

The results of the study indicated a significantly lower percentage reduction in weight for maize grains stored in *Jatropha curcas*-infused hermetic bottles compared to those stored in non-infused bottles. The maize grains in *Jatropha*-infused bottles demonstrated a reduced weight loss of 0.5%, which is a marked improvement over the non-*Jatropha curcas* infused bottles which recorded 48.96% weight loss after six months of storage (Table 2). This suggests that the *Jatropha* infusion has a dual effect: it acts as a natural insect repellent, preventing insect-related weight loss due to feeding damage, while simultaneously maintaining the overall moisture content of the grains more effectively (Valdez-Ramírez *et al.*, 2023; Choudhary *et al.*, 2024) [28, 29]. This outcome is supported by the notion that the toxic

Results and discussion

Survivorship percentage of *Sitophilus zeamais* Survival rate of *Sitophilus zeamais* in *Jatropha curcas* and non-*Jatropha curcas* infused Hermetic Plastic Bottles

The results showed that *S. zeamais* survivorship in *Jatropha*-infused bottles was near zero within 7 to 9 days of exposure. This could be attributed to the immediate toxic effects of *Jatropha* compounds, which likely caused a higher mortality rate in the early stages of the experiment (Tsegab and Eman, 2023) [25]. While hermetic conditions alone took more than 9 days to induce significant 10% mortality, the *Jatropha* infusion accelerated the mortality process, leading to a much quicker eradication of the pest population (Table 1). In *Jatropha*-infused hermetic plastic bottles, *S. zeamais* survival rates were dramatically reduced compared to the non-infused control group. This suggests that the toxic properties of *Jatropha*, in combination with the low oxygen conditions, create a particularly inhospitable environment for *S. zeamais* as opposed to the slower suffocation process observed in non-infused hermetic conditions. The non-*Jatropha* infused hermetic bottles may take a longer period to achieve comparable levels of mortality. *S. zeamais* survivors in non-infused bottles exhibited longer lifespans, likely due to a slower progression of oxygen depletion, tolerance of some species to survive longer under low-oxygen and a lack of additional toxic stressors (Yewle *et al.*, 2022; Sarazin *et al.*, 2023) [26, 27]. This highlights the potential benefits of incorporating plant-based infusions such as *Jatropha curcas* into hermetic storage systems, particularly in regions where pest control is a significant challenge and chemical pesticides are not desirable or accessible.

components in *Jatropha curcas* may inhibit the activity of insect pests or cause premature mortality, thereby reducing the damage typically seen in maize stored under traditional methods (Tchegueni *et al.*, 2023; Valdez-Ramírez *et al.*, 2024) [30, 31]. The comparative analysis of the percentage reduction in weight between maize stored in *Jatropha*-infused and non-infused hermetic plastic bottles reveals the added benefit of using a natural plant-based infusion in storage systems. While both storage methods benefit from the oxygen-limiting conditions that characterize hermetic systems, the infusion of *Jatropha curcas* appears to offer an additional layer of protection against both pest infestation and weight loss. This suggests that the chemical properties of *Jatropha curcas* may interact synergistically with the hermetic conditions to prolong the retention of grain mass by limiting both biotic and abiotic factors contributing to weight loss.

Table 2: Percentage reduction in weight of maize grains stored in *Jatropha curcas*-infused hermetic plastic bottles and non-*Jatropha curcas* infused hermetic plastic bottles for six months,

Days	Storage materials/ Percentage reduction in weight of maize grains	
	<i>Jatropha curcas</i> Infused Hermetic Plastic Bottle (%)	Non- <i>Jatropha curcas</i> Infused Hermetic Plastic Bottle
30	0±0.000 ^a	13.00±0.289 ^a
60	0±0.000 ^a	17.30±0.202 ^b
90	0.4±0.058 ^b	28.70±0.087 ^c
120	0.4±0.058 ^b	34.70±0.029 ^d
150	0.5±0.058 ^b	41.23±0.017 ^e
180	0.5±0.058 ^b	48.96±0.064 ^f

The results indicate the mean values of triplicate measurements ± standard error of the mean. Mean values within the same column that are denoted by the same letter do not show significant differences at $p \leq 0.05$.

Moisture retention of maize grains stored in *Jatropha curcas* and non-*Jatropha curcas* infused hermetic plastic bottles

The results of moisture retention of maize grains stored in *Jatropha curcas* and non-*Jatropha curcas* infused-hermetic plastic bottles revealed that maize grains stored in *Jatropha*-infused hermetic bottles retained more moisture compared to those stored in non-infused bottles (Table 3). The reduction in moisture content in the *Jatropha*-infused bottles was significantly lower, showing a decrease range of 0.00 to 0.23% over the period of six months while non-*Jatropha curcas* infused hermetic plastic bottles recorded between 2.58 to 15.46% (Table 3). This suggests that the toxic effects of *Jatropha curcas* may not only reduce pest-induced damage but also contribute to enhanced moisture retention in the grains. Several possible explanations can account for this observation. Firstly, the diminished insect activity in the bottles containing *Jatropha* likely led to a reduction in physical damage to the grains, such as punctures or feeding scars, which can hasten moisture loss. By deterring insects from consuming the grains, *Jatropha*

curcas may have played a role in slowing the rate of water evaporation. Furthermore, *Jatropha curcas* could also have indirect effects on the microclimate within the hermetic containers, potentially affecting the air's moisture retention capacity inside the bottle. Another consideration is that the chemical constituents of *Jatropha curcas* might modify the osmotic characteristics of the maize kernels, thereby impacting the grains' ability to retain water. Although this mechanism warrants further exploration, it may clarify why the moisture content in the *Jatropha*-infused containers decreased at a slower rate. This is particularly important in the context of long-term storage, where maintaining the proper moisture level is crucial for grain quality and prevention of spoilage. In non-infused hermetic bottles, the moisture levels in maize grains exhibited a gradual yet consistent decline over time. This phenomenon is likely attributed to the slow and ongoing transfer of water vapor from the grains into the air inside the sealed container. While hermetic conditions effectively block external humidity from entering, the air within the container can still promote the movement of moisture away from the grains.

Table 3: Percentage moisture retention of maize grains stored in *Jatropha curcas* and non-*Jatropha curcas*-infused-hermetic plastic bottles for six months

Days	Storage materials/ Percentage reduction in weight of maize grains	
	<i>Jatropha curcas</i> Infused Hermetic Plastic Bottle (%)	Non- <i>Jatropha curcas</i> Infused Hermetic Plastic Bottle
30	100.00±0.000 ^a	97.42±0.349 ^e
60	100.00±0.000 ^a	93.18±0.439 ^d
90	99.85±0.087 ^a	89.39±0.436 ^c
120	99.85±0.087 ^a	86.21±0.087 ^b
150	99.77±0.043 ^a	84.85±0.087 ^a
180	99.77±0.043 ^a	84.54±0.046 ^a

The results indicate the mean values of triplicate measurements ± standard error of the mean. Mean values within the same column that are denoted by the same letter do not show significant differences at $p \leq 0.05$.

Fungal load determination of maize grains stored in *Jatropha curcas*-infused hermetic plastic bottle and non-*Jatropha curcas* infused hermetic plastic bottle

The fungal load of maize grains stored in *Jatropha curcas*-infused and non-*Jatropha curcas* infused hermetic plastic bottles was investigated to determine the effectiveness of these storage conditions in controlling fungal growth. Results show that maize grains stored in *Jatropha*-infused hermetic plastic bottles exhibited a significantly too few to quantify fungal load compared to those stored in non-infused hermetic bottles as storage days progressed to 150 to 180 days (Table 4). The antifungal effects of *Jatropha curcas* could be attributed to the bioactive compounds present in the plant compounds such as curcumin protein, 9,12-octadecadienoic acid, n-Hexadecanoic acid, and squalene,

which may act directly on fungal cells by disrupting their cell membranes or inhibiting essential metabolic pathways (Lai *et al.*, 2023; Nadège *et al.*, 2024) [32, 33]. These compounds may not only limit fungal growth but may also reduce the capacity of fungal spores to germinate in the first place (Manyama *et al.*, 2024) [34]. Additionally, the reduced presence of *Sitophilus zeamais* in the *Jatropha*-infused containers, due to the insecticidal properties of *Jatropha*, likely further contributed to the lower fungal load as insects, particularly *S. zeamais*, are often vectors for fungal spores (Hong *et al.*, 2023; Meiqi *et al.*, 2024) [35, 36], and by limiting pest populations, the risk of fungal contamination is reduced. As a result, the *Jatropha*-infused hermetic storage system created a more controlled environment that not only restricted oxygen and pest activity but also provided an extra barrier against fungal growth.

Table 4: Fungal load determination of maize grains stored in *Jatropha curcas*-infused hermetic plastic bottle and non-*Jatropha curcas* infused hermetic plastic bottle

Days	Storage materials	
	<i>Jatropha curcas</i> -Infused Hermetic Plastic Bottle (log ₁₀ cfu/g)	<i>Jatropha curcas</i> -infused hermetic plastic bottle (log ₁₀ cfu/g)
30	TFTQ	TFTQ
60	TFTQ	TFTQ
90	TFTQ	TFTQ
120	TFTQ	TFTQ
150	TFTQ	3.8X10 ⁶
180	TFTQ	4.6X10 ⁶

TFTQ= Too few to quantify

Germination assessment of maize grains stored in *Jatropha curcas*-infused hermetic plastic bottle and non-*Jatropha curcas*-infused hermetic plastic bottle

In this study, maize grains stored in non-*Jatropha*-infused hermetic plastic bottles showed a sharp reduction in germination percentage over the storage period (Table 5). The decrease in germination was likely due to a combination of factors, including natural aging processes, moisture fluctuations, and potential fungal contamination, despite the protective effect of hermetic storage (Martin *et al.*, 2022; Shango *et al.*, 2024; Waterworth *et al.*, 2024; Meitankeisangbam *et al.*, 2024) [37, 38, 39, 40]. On average, the germination percentage in non-infused hermetic containers decreased to 70% after 30 days of storage and progressively down to 0% after six months suggesting that while hermetic storage provides some preservation of seed quality,

additional factors are still at play that may affect seed viability (Odjo *et al.*, 2022) [18]. However, the maize grains stored in *Jatropha curcas* infused hermetic plastic bottles exhibited a higher germination percentage compared to those stored in non-infused bottles. The seeds stored in *Jatropha*-infused containers showed a slower rate of germination decline, with a reduction in germination percentage of only 10% over the storage period of six months, which was significantly lower than the reduction observed in the non-infused hermetic bottles (Table 5). Therefore, infusion of *Jatropha curcas* not only prevented insect damage but also seemed to offer protection against potential fungal contamination, which can reduce germination by affecting seed integrity (Haider *et al.*, 2024; Selemani *et al.*, 2025) [41, 42].

Table 5: Germination percentage assessment of maize grains stored in *Jatropha curcas*-infused hermetic plastic bottle and non-*Jatropha curcas*-infused hermetic plastic bottle

Days	Storage materials	
	<i>Jatropha curcas</i> -Infused Hermetic Plastic Bottle (%)	Non- <i>Jatropha curcas</i> -infused hermetic plastic bottle
30	100.00±0.00 ^a	70.00±5.77 ^a
60	100.00±0.00 ^a	50.00±5.77 ^b
90	100.00±0.00 ^a	30.00±5.77 ^c
120	100.00±0.00 ^a	0.00±0.00 ^d
150	100.00±0.00 ^a	0.00±0.00 ^d
180	90.00±5.77 ^a	0.00±0.00 ^d

The results indicate the mean values of triplicate measurements ± standard error of the mean. Mean values within the same column that are denoted by the same letter do not show significant differences at p≤0.05.

Conclusion

The findings from this study have significant implications for the design and implementation of grain storage systems, particularly in regions prone to insect infestations and where humidity regulation is critical for maintaining grain quality. The integration of *Jatropha curcas* infusion into hermetic storage systems presents a promising alternative to chemical insecticides, offering an environmentally friendly and sustainable method for preserving maize grains. In conclusion, the infusion of *Jatropha curcas* into hermetic plastic bottles significantly enhances the quality of maize grains during storage.

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