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The effects of oxygen scavenging on survival of *Tribolium castaneum* (Herbst) and shelf-life of foxtail millet

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Oxygen scavenging offers an oxygen free atmosphere inside packages that could help in controlling of insects and enhance the shelf-life of the packaged grains. An experiment was carried out by packing foxtail millet rice using four different packaging materials with and without *T. castaneum* and oxygen absorbers to assess their effect on the shelf life of grain by reducing oxidation of fatty acids during 2017-18 at UAS, GKVK, Bangalore. Results obtained from the study revealed that in treatments with oxygen scavenger and the *T. castaneum* which were released initially were dead due to complete evacuation of oxygen by oxygen absorbers from within the pouches, and no insects emerged throughout the experimental period. The extent of damage to grains in the pouches with oxygen scavenger was only 1.4-1.6%, which could have been the damage that existed even before filling up the pouches. On the other hand, the pouches without oxygen scavenger, the *T. castaneum* damage ranged from 6.4-11.6%. Nutritional composition was relatively unaffected in the pouches containing oxygen scavenger, as compare to the pouches without oxygen scavenger.

Keywords: Fatty acid, Foxtail millet, Oxygen scavenger, Shelf life, *T. castaneum*

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Millets are cereal crops belonging to the grass family Poaceae, primarily grown on marginal lands in dry areas of subtropical and tropical regions of Asia and Africa[1]. Their cultivation is expected to offers both nutritional and livelihood security for human beings and also feed security for diverse livestock populations in dryland regions of rural India[2]. In India, these millets are grown in every state and region, but the distribution of millets, production is not uniform across the states. In India, millets have been mentioned in some of the oldest Yajurveda texts, identifying foxtail millet (*priyangava*), Barnyard millet (*aanava*) and black finger millet (*shyaamaka*), thus indicating that millet consumption was very common, pre-dating to the Indian Bronze Age (4,500 BC). Rich in protein, dietary fibre, an array of vitamins and minerals, include these millets to control blood sugar, lose weight, boost immunity and protect heart health. According to Ayurveda, Foxtail millet increases vata dosha but balances doshas related to pitta, kapha and blood tissues[3]. Foxtail millet ranks second in the world production and consumption of millets. These millets are also known as the Italian millet. Its grain is used for human consumption and also as feed for poultry and cage birds[4]. Grain filled pouches are prone to insect infestation and product deterioration results owing to the presence of oxygen in the head space and inter-granular spaces. The same can be utilized by stored grain insects for their reproduction and development. Due to the presence of oxygen, multiplication of insect continues and product deterioration also occurs due to oxidative process of fats present in the grains and result in the development of rancidity[5]. The use of oxygen absorbers is one of the most widely used active packaging technology in packaged foods today for controlling of oxygen levels in food packages[6]. The oxygen absorbers are designed to reduce oxygen levels to less than 100 ppm in package head space. *Tribolium castaneum* (Herbst) is a serious pest on husked foxtail millet and is a major restraining factor for extended storage and improving their shelf life, it was thus decided to address the problem through active packaging concept by means of an oxygen scavenging system.

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Methodology

A laboratory investigation was conducted during 2017-18 at AICRP on PHET, UAS, GKVK, Bangalore. Red flour beetle (*Tribolium castaneum*) culture was obtained from a PCI (PEST CONTROL OF INDIA), Bengaluru, Karnataka. Cultures were maintained on gram flour in a plastic container fitted with a mesh lid. Freshly dehulled foxtail millet rice containing moisture 11.5±0.65 and free from insect infestation were used. Different packaging pouches used in the study include LDPE, HDPE, multi-layered pouches supplied by Swiss Pac and Ecotact of one kilo capacity. Each pouch was filled with 850 g of foxtail millet, into each pouch 40 freshly emerged *T. castaneum* adults (<24 h old) were released. The pouches were sealed instantly by using a Band Sealer after releasing insects and after including a 200cc oxygen absorber and then labelled the treatments as mentioned in Table 1. Each treatment was replicated thrice. The adult insects were allowed to feed on grains in each treatment. After the completion of the experimental period (90 days), pouches were opened and the total number of live adult insects in each treatment were counted and recorded. The extent of grain damage was calculated by counting the number of damaged grains caused by *T. castaneum*. These insects damage the grains at the germ region in a 'V' shape. By taking thousand grains from each pouch, the number of damaged and undamaged grains were counted thereby the per cent grain damage was worked out.

Table 1 — Details of experiment

Sl. No.	Treatments	Treatment
1	T_1	LDPE Pouch with insects and with 200 cc O_2 Absorber
2	T_2	LDPE Pouch with insects and without O_2 Absorber
3	T_3	LDPE Pouch without insects and without O_2 Absorber
4	T_4	HDPE Pouch with insects and with 200 cc O_2 Absorber
5	T_5	HDPE Pouch with insects and without O_2 Absorber
6	T_6	HDPE Pouch without insects and without O_2 Absorber
7	T_7	Multilayer Pouch with insects and with 200 cc O_2 Absorber
8	T_8	Multilayer Pouch with insects and without O_2 Absorber
9	T_9	Multilayer Pouch without insects and without O_2 Absorber
10	T_{10}	Multilayer (ECOTACT) Pouch with insects and with 200cc O_2 Absorber
11	T_{11}	Multilayer (ECOTACT) Pouch with insects and without O_2 Absorber
12	T_{12}	Multilayer (ECOTACT) Pouch without insects and without O_2 Absorber

Estimation of proximate composition of grains before and after including oxygen scavengers

The foxtail millet rice that was obtained for experiment was subjected to proximate analysis for estimation of carbohydrate, protein, ash, fat, fibre and free fatty acids before and after addition of oxygen scavengers. The procedures followed for the estimation of the above parameters are described below.

Determination of fat

The fat content of foxtail millet rice samples was determined by solvent extraction method[7]. A sample of foxtail millet rice was grounded (coarsely) in a pestle and mortar. A known quantity of this powder was taken (about 10 g) in a paper thimble was plugged with cotton. The thimble containing the sample was placed in Soxhlet extractor. Pre-weighed receiver flask was filled with petroleum ether to its 2/3rd capacity and the apparatus was set up for oil extraction. The petroleum ether in the receiver flask was then heated over a heating mantle to produce vapor which was circulated through the condenser and made to fill the extraction chamber containing the sample in a thimble. During this process, the ether passed through the sample and leached the fat content of the material into the ether. A siphoning mechanism allowed the fat-laden petroleum ether in the extraction chamber to circulate back to the receiver flask intermittently and this process was repeated. After 5-6 h of extraction, the unit was allowed to cool and was detached. The thimble was taken out and dried under a fan to evaporate the ether. The receiver was heated in a water bath and dried under the fan to evaporate the solvent. The flask was then weighed to know the quantity of oil extracted. The fat content of the sample was calculated as:

$$\text{Fat}\,(\%) = \frac{\text{Weight of oil (g)}}{\text{Weight of sample}} \times 100$$

Determination of fiber

The fiber contents of foxtail millet rice samples were estimated using the procedure described by Raguramulu and his associates (2003)[8]. About 5-10 g of moisture and the fat-free sample was weighed into a 500 mL beaker and to this 200 mL of boiling

0.255 N (1.25% w/v), sulphuric acid was added. The mixture was boiled for 30 min and during boiling the volume was maintained constant by the addition of distilled water at frequent intervals (a glass bead placed in the beaker helped smooth boiling). At the end of 30 min, the mixture was filtered through a muslin cloth and the residue was washed with hot water until free from acid. The material was then transformed to the same beaker and 200 mL of boiling 0.313N (1.25%) NaOH was added. After boiling for 30 min (maintaining the volume constant by adding distilled water), the mixture was again filtered through another cloth. The residue was washed with hot water to make it free from alkali followed by washing with alcohol and ether. It was transferred to a crucible, dried overnight at 80-100°C in a hot air oven and the initial weight of crucible with the dry sample was noted (We). The crucible was then heated in a muffle furnace at 600°C for 2-3 h, cooled and weighed again (Wa). The difference in the weights (We-Wa) represented the weight of the crude fiber.

$$\text{Crude fibre content (\%)} = \frac{[100-(\text{moisture}^{*}+\text{fat}^{*})]\times(\text{We}-\text{Wa})}{\text{Wt. of sample taken (moisture and fat free samples)}} \times 100$$

(Note: * g/100 g of the sample)

Determination of protein

The protein content of the foxtail millet rice grains was determined by using the micro Kjeldhal method[9]. The protein estimation procedure consisted of three steps namely, digestion, distillation and titration.

Digestion

A known weight of the sample (0.2 g) was taken and transferred to a micro Kjeldhal flask and a pinch of catalytic mixture and 2 mL of concentrated H_2SO_4 were added. The mixture was heated for about 2-21/2 h till a clear greenish color solution was formed. The experiment was triplicated and a blank was also kept for digestion.

Distillation

The digest was transferred to the distillation unit. The same Kjeldhal flask was washed twice with a little quantity of water and washings were also transferred to the distillation unit. To this, 10-15 mL of 40% NaOH was added and steam distilled. The liberated ammonia (NH_3) was collected in 25 mL of two per cent boric acid containing a few drops of mixed indicator. When all the liberated ammonia was collected, the solution was titrated against 0.05N H_2SO_4 and the amount of nitrogen and thereby the protein content present in the sample was estimated as follows:

$$\text{Nitrogen (\%)} = \frac{(A-B)\times 0.05\times 14\times 100}{W}$$

$$\text{Protein (\%)} = \%\ N \times 6.25$$

Where,

A = volume of 0.05 N H_2SO_4 used (titer value) for the sample, mL

B = volume of 0.05 N H_2SO_4 used (titer value) for the blank, mL

Moisture content

The moisture content of foxtail millet rice sample was determined by using an electric hot air oven. Three-grain samples weighing 5-10 g each was taken in non-corrosive metal dishes and weighed (W_1). The samples were placed in a hot air oven maintained at 105°C for 24 h. After taking out from the oven, the samples were cooled in a desiccator and weighed. The samples were again kept in the oven, heated for two hours, cooled and the weight was recorded. This procedure was repeated until a constant weight (W_2) of the sample was attained. The average moisture content on the wet basis of these samples was calculated using the following equation:

$$\text{Moisture content (\% wb.)} = \frac{W1-W2}{W1}\times 100$$

Where,

W_1 = Initial weight of sample (g), W_2 = Final weight of sample (g)

Determination of ash

The ash contents of foxtail millet rice samples were estimated by following the method described by Raguramulu and his associates (2003)[8]. About two grams of the sample was weighed accurately into a porcelain crucible (which was previously heated to 600°C cooled and weighed). The crucible was placed on a clay pipe triangle and heated over a low flame until all the material was completely charred. The crucible was then heated in a muffle furnace for about 3-4 h at 600°C, cooled in a desiccator and weighed. The crucible was again heated in the muffle furnace as before, cooled and again weighed. This process was repeated till two consecutive weights were the same and the ash was almost white (Ox greyish) in color.

$$\text{Ash content (\%)} = \frac{\text{weight of ash (g)}}{\text{weight of sample}}\times 100$$

Determination of carbohydrate

The available carbohydrate content in the foxtail millet rice was determined by the method of differences i.e., by subtracting from 100, the sum of values (per 100 g) of moisture, protein, ash and crude fiber.

Free fatty acids

The free fatty acid contents of foxtail millet rice samples were estimated by following the method described Sadasivam and Manickam (2008)[10]. Two grams of sample was dissolved in 50 mL of neutral solvent (25 mL ether, 25 mL 95% alcohol and 1 mL of 1% phenolphthalein indicator and neutralised by 0.1 N KOH). To it, a few drops of phenolphthalein indicator was added and titrated against 0.1 N KOH till pink colour which persisted for 15 seconds was obtained.

$$\text{Free fatty acids } \left(\frac{\text{mg of KOH}}{\text{g}}\right) = \frac{\text{Titire value} \times \text{Normality of KOH} \times 56.1}{\text{Weight of sample (g)}} \times 100$$

Statistical analysis

The data was suitably transformed by $\sqrt{X+0.5}$ transformations and was analysed using one-way analysis of variance.

Results and Discussion

Emergence of insects in different treatments

Forty insects were released to all the treatments initially except in the controls (A1B3, A2B3, A3B3 and A4B3). At the end of experimentation, the total adults survived were calculated. The number of insects recorded in different treatments is shown in Table 2. In the treatment A1B1 with LDPE pouch, which contained insects and oxygen absorber, all insects were found dead in the first day itself due to the complete removal of oxygen by oxygen absorber and thus, no insects emerged throughout the ninety days. In the treatment A1B2, the pouches containing only insects, but no oxygen absorbers, seventy adults were recorded at the end of ninety days. However, in the control pouches, 21 *T. castaneum* were found. This shows the presence of existing infestation in the foxtail millet, which must have come from the insect contaminated processing machinery. In the HDPE pouches which contained both oxygen absorbers and insects (A2B1), no live insects were recorded at the end of ninety days. In the HDPE treatment A2B2 which contained only insects and no oxygen absorber, the live insect numbers are increased from 40 to 69.67 at the end of experimentation. However, in the control pouches no insects were present initially, but at the end of experimentation, 30.33 numbers of insects were found due to the existing infestation from processing machinery. In Swiss Pac multi-layered pouch treatment A3B1 with both oxygen absorber and insects, no insects were present at the end of experimentation as similar to other treatments that contained oxygen absorbers. The A3B2 treatment with only insects, but without oxygen absorber recorded a gradual increase in insect number and reached 61.33 by the end of ninety days. In the control, A3B3 treatment pouches which did not contain either the oxygen absorbers or the test insects in that pouch, the numbers of *T. castaneum* increased from zero to the 24.33. The treatment A4B1 with multi-layered (Ecotact) pouch which contained both insects and oxygen absorber, recorded zero number of insects at the end of experimentation. The treatment A4B2 with only insects and without oxygen absorber recorded of 40 insects initially. The insects then started to increase in numbers day by day and reached 67.33 at the end of experimentation. The control A4B3 pouches without oxygen absorber or insects recorded an initial zero number of insects, which gradually increased and reached 31.67 at the end of 90 days.

Table 2 — Extent of grain damage by insects

Treatment	Treatment levels	Adult emergence	Damage (%)
T1	A1B1	0.00 (0.71)	1.50 (1.41)
T2	A1B2	70.00 (8.39)	11.57 (3.47)
T3	A1B3	21.00 (4.62)	6.40 (2.62)
T4	A2B1	0.00 (0.71)	1.72(1.49)
T5	A2B2	69.67 (8.38)	10.02 (3.22)
T6	A2B3	30.33 (5.55)	7.03 (2.74)
T7	A3B1	0.00 (0.71)	1.65 (1.46)
T8	A3B2	61.33 (7.86)	11.05 (3.40)
T9	A3B3	24.33 (4.98)	7.36 (2.80)
T10	A4B1	0.00 (0.71)	1.40 (1.38)
T11	A4B2	67.33 (8.23)	10.52 (3.32)
T12	A4B3	31.67 (5.67)	7.26 (2.78)
SEM		0.1251	0.1169
CD at 0.05%		0.3652	0.3411

A1 = Low Density Polyethylene (LDPE), A2 = High Density Polyethylene (HDPE), A3 = Swiss Pac (multi-layered pouch), A4 = Ecotact (multi-layered pouch), B1 = Pouch with insects and with oxygen absorber, B2 = Pouch with insects and without oxygen absorber, B3 = Pouch without insects and without oxygen absorber. Values in parenthesis are $\sqrt{x+0.5}$ transformed values; * mean value and transformed values in brackets; The significance level is 0.05%; ** All values are mean of three replications.

Effect of infestation on extent of grain damage

The extent of damage was calculated by counting the number of damaged grains caused by *T. castaneum* and further evaluating the percent damage in each treatment. The results are represented in Table 2 and Figure 1. The treatments (A1B1, A2B1, A3B1 and A4B1) which contained an oxygen absorber, in these pouches damage of grains was found to be 1.57%, 1.72%, 1.65% and 1.40%, respectively. The grain damage recorded in these treatments was due to the insects present in the grains before filling into the pouches.

The treatments A1B2, A2B2, A3B2 and A4B2 which contained only insects and no oxygen absorbers, the extent of grain damage was found to be 11.57, 10.02, 11.05 and 10.52%, respectively. The grain filled pouches without any insects or oxygen absorber recorded the emergence of insects five weeks after the commencement of the experiment in A1B3, A2B3, A3B3 and A4B3 treatments and at the end of experiments, the number of insects increased to 21, 30.33, 24.33 and 31.67 numbers, respectively. The damage caused by these insects was found to be 6.40, 7.03, 7.36 and 7.26%, respectively.

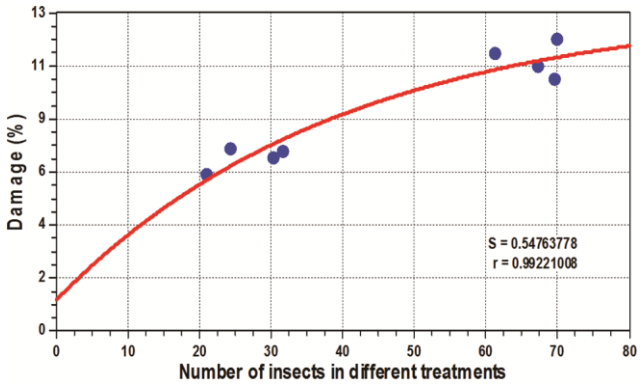

Fig. 1 — Effect of *Tribolium castaneum* infestation on extent of grain damage

Proximate analysis: Initial observations

Before the starting of the trial, proximate analysis of foxtail millet was carried out. The initial moisture, protein, crude fat, crude fibre, total ash, carbohydrate and free fatty acid content of the foxtail millet rice used was found to be 11.50, 12.10, 3.91, 4.51, 2.91, 72.2 and 0.7%, respectively (Table 3).

Proximate analysis – final observations

The results of the proximate analysis of foxtail millet rice at the end of 90 days of the confirmatory trial were presented below.

Moisture content

The treatments with grain-filled pouches with oxygen absorbers and insects recorded a moisture content of 10.27-10.89% by the end of the experiment (90 days). This moisture content was less than the initial moisture content of 11.50%.

Protein content

The foxtail millet rice pouch with insects and oxygen absorber recorded an initial protein content of

Table 3 — Proximate composition of foxtail millet rice in different treatments after 90 days

Treatments	Treatment levels	Moisture (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrates (%)	Free fatty acids (%)
T1	A1B1	10.82 (3.36)	11.51 (3.46)	3.70 (2.05)	4.32 (2.20)	2.41 (1.71)	71.50 (8.49)	1.12 (1.27)
T2	A1B2	10.27 (3.28)	11.41 (3.44)	3.24 (1.93)	4.10 (2.14)	2.32 (1.68)	70.41 (8.42)	1.92 (1.56)
T3	A1B3	10.84 (3.37)	11.12 (3.41)	3.10 (1.90)	4.21 (2.17)	2.42 (1.71)	69.01 (8.34)	2.45 (1.72)
T4	A2B1	10.86 (3.37)	11.61 (3.47)	3.70 (2.05)	4.22 (2.17)	2.30 (1.67)	71.32 (8.47)	0.91 (1.19)
T5	A2B2	10.29 (3.28)	11.32 (3.44)	3.11 (1.90)	4.00 (2.12)	2.51 (1.73)	70.12 (8.40)	1.73 (1.49)
T6	A2B3	10.79 (3.36)	10.80 (3.36)	2.91 (1.85)	3.71 (2.05)	2.36 (1.69)	70.21 (8.41)	2.23 (1.65)
T7	A3B1	10.89 (3.37)	11.63 (3.48)	3.62 (2.03)	4.32 (2.20)	2.24 (1.66)	71.22 (8.45)	0.84 (1.16)
T8	A3B2	10.29 (3.28)	11.34 (3.43)	3.41 (1.98)	3.70 (2.05)	2.41 (1.71)	68.50 (8.31)	1.42 (1.39)
T9	A3B3	10.33 (3.29)	10.91 (3.37)	2.83 (1.82)	3.80 (2.07)	2.32 (1.68)	69.31 (8.36)	1.95 (1.57)
T10	A4B1	10.75 (3.35)	11.53 (3.47)	3.82 (2.08)	4.44 (2.22)	2.51 (1.73)	71.43 (8.48)	0.93 (1.20)
T11	A4B2	10.32 (3.29)	11.51 (3.46)	3.21 (1.93)	3.90 (2.10)	2.43 (1.71)	70.01 (8.40)	1.29 (1.34)
T12	A4B3	10.61 (3.33)	10.72 (3.35)	3.42 (1.98)	3.91 (2.10)	2.34 (1.69)	68.20 (8.29)	2.11 (1.62)
SEM		0.0869	0.1189	0.0261	0.0300	0.0107	0.0157	0.0126
CD at 0.05%		0.2536	0.3469	0.0761	0.0876	0.0312	0.0457	0.0368

A1 = Low Density Polyethylene (LDPE), A2 = High Density Polyethylene (HDPE), A3 = Swiss Pac (multi-layered pouch), A4 = Ecotact (multi-layered pouch), B1 = Pouch with insects and with oxygen absorber, B2 = Pouch with insects and without oxygen absorber, B3 = Pouch without insects and without oxygen absorber. Values in parenthesis are √x+0.5 transformed values; * mean value and transformed values in brackets; The significance level is 0.05%; ** All values are mean of three replications.

12.10%, while it ranged from 10.7-11.6% in different treatments at the end of the experiment. Relationship between Insect damage and final protein content in different treatments is presented in Figure 2. Among the treatments, the treatments with oxygen absorbers (A1B1, A2B1, A3B1 & A4B1) recorded a protein content of 11.51, 11.61, 11.63 and 11.53%. The lower levels of protein content were recorded in treatments A1B3, A2B3, A3B3 and A4B3. Thus, the treatments with oxygen absorbers retained higher protein levels, in comparison to the initial level recorded at the beginning of the experiment.

Crude fat content

The foxtail millet rice pouch with insects and oxygen absorber had an initial fat content of 3.91% while, in other treatments, it varied between 3.1-3.7% at the end of the experiment. Among these, the treatments with oxygen absorbers (A1B1, A2B1, A3B1 & A4B1) recorded a fat content of 3.70, 3.70, 3.62 and 3.82%. The lower levels of fat content were recorded in treatments A1B3, A2B3, A3B3 and A4B3. Thus, the treatments with oxygen absorbers retained a higher fat level, in comparison to the initial level recorded at the beginning of the experiment.

Crude fibre content

Fibre content in foxtail millet rice pouches with insects and oxygen absorber at initial stages was observed to be 4.51% while, it ranged between 3.7-4.4% in different treatments at the end of the experiment. Among the treatments, the treatments with oxygen absorbers (A1B1, A2B1, A3B1 & A4B1) recorded a fibre content of 4.32, 4.20, 4.32 and 4.44%. The lower levels of fibre content were recorded in treatments A1B3, A2B3, A3B3 and A4B3. Thus, the treatments with oxygen absorbers retained higher fibre level, in comparison to the initial level.

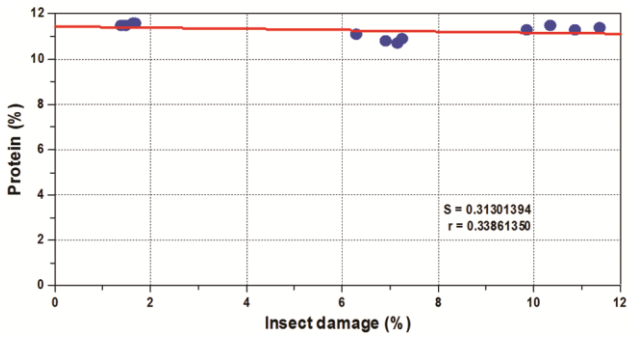

Fig. 2 — Relationship between Insect damage and final protein content in treatments

Total ash content

The foxtail millet rice pouch with insects and oxygen absorber recorded an initial ash content of 2.91% while, it ranged from 2.3-2.5% in different treatments at the end of the experiment. Among the treatments, the treatments with oxygen absorbers (A1B1, A2B1, A3B1 & A4B1) recorded an ash content of 2.41, 2.30, 2.24 and 2.51%. The lower levels of ash content were recorded in treatments A1B3, A2B3, A3B3 and A4B3. Thus, the treatments with oxygen absorbers retained higher ash content levels, in comparison to the initial level recorded at the beginning of the experiment.

Carbohydrates

Initial carbohydrate levels in the foxtail millet rice pouch with insects and oxygen absorber was recorded to 72.21% while, it ranged from 68.2-71.5% in different treatments at the end of the experiment. Among the treatments, the treatments with oxygen absorbers (A1B1, A2B1, A3B1 & A4B1) recorded a carbohydrate content of 71.50, 71.33, 71.2 and 71.43%. The lower levels of carbohydrates content were recorded in treatments A1B3, A2B3, A3B3 and A4B3. Thus, the treatments with oxygen absorbers retained a higher carbohydrates content level, in comparison to the initial level.

Free fatty acids

The free fatty acids profile in different treatments showed that the treatments A1B1, A2B1, A3B1 & A4B1 had the lowest free fatty acid levels (1.12, 0.91, 0.84 and 0.93%, respectively). The highest percentage of free fatty acids were recorded in the control treatments A1B3 (2.45%), A2B3 (2.23%), A3B3 (1.95%) and A4B3 (2.11%). The treatments with only insects (A1B2, A2B2, A3B2 and A4B2) had free fatty acid values of 1.92, 1.73, 1.42 and 1.29%, respectively. Thus, the treatments which included the oxygen absorbers had the lowest levels of free fatty acids, with values ranging from 0.84-1.29. Relationship between Insect damage and final Free fatty acid content in different treatments is presented in Figure 3. Correlation analysis of free fatty acid levels in different treatments with that of final levels grain damage by the test insect in different treatment showed a strong positive association (r=0.78), indicating that the increase in insect damage of grains resulted in an increased level of free fatty acids in different treatments.

The overall assessment of the proximate composition of grains filled in pouches under

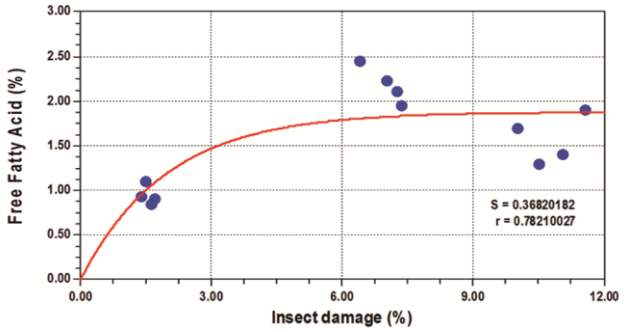

Fig. 3 — Relationship between insect damage and final free fatty acid content in different treatments

different treatments indicated that treatments that contained both insects and oxygen absorbers were superior to the other treatments that maintained low free fatty acid contents (0.95%) followed by pouches containing only insects, but without oxygen absorber (1.5%) and pouches without oxygen absorbers and insects (2.45%). The nutrients composition was also higher in pouches containing insects and oxygen absorbers followed by pouches containing only insects and pouches without insects and oxygen absorbers.

If the value of free fatty acid exceeds three per cent, the stored grains show rancidity and are unfit for consumption[11]. The pouches containing treatments without oxygen absorber and insects reached to a higher level of 2.45%, suggested that these pouches were rancid and unfit for consumption whereas the pouches containing oxygen absorber recorded the lowest level of free fatty acid (0.95%). Thus, the oxygen absorber helps in controlling oxidation process in grain filled pouches compared to those which do not contain the oxygen absorber.

Conclusion

For survival and development of insects, oxygen is necessary in retail packages. The results of the present investigation show that oxygen absorbers are quite efficient in removing oxygen completely from within the pouches and maintain zero percent of oxygen within and achieve 100% mortality of insects within a day. Oxygen absorbers were effective irrespective of stages and, all the stages of insects are killed due to anoxia and no progeny development was observed throughout the experimental period in the pouches contained oxygen absorbers. Thus, use of oxygen absorber within retail grain-filled pouches is a novel way of controlling insects and also the prevention of rancidity and off-odours. The results of the present investigation have clearly demonstrated this.

Conflict of Interest

Authors declare no conflict of interest

Authors' Contributions

SS: Conceptualization, design, drafting, editing; KKHD & DSD: Data collection, reviewing, writing. All authors read and approved the final manuscript

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