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Effect of vacuum storage of wheat (*Triticum aestivum*) grain on the granary weevil, *Sitophilus granarius* and wheat quality

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ABSTRACT

In laboratory experiments, 30 adults of the granary weevil, *Sitophilus granarius* (L.) were transferred onto 1.3 kg wheat (*Triticum aestivum* L.) grain in open 2 l vacuum bags. The grain had an initial m.c. of 9.5, 12.5, 14.0 and 15.5%. Beetles were allowed to feed and oviposit for 7 days before drawing a vacuum in the vacuum bags used for this purpose. The vacuum aimed for was 50%, reducing the ambient oxygen content from 20.9% to about 10.5%. For each tested parameter, three bags were flushed with nitrogen to restore ambient pressure and again vacuumed once, twice or three times to further reduce the initial oxygen content to 5.3, 2.6 and 1.3% respectively. Bags were subsequently stored at 20°C for 3, 6 , 12 or 24 months. Only one beetle was found to have survived three months of storage and no survivors were found after longer storage periods. Grain quality was not affected by the presence of weevils nor the initial residual oxygen content, while initial moisture content had a marked effect. It is therefore possible that the reduced pressure and resulting oxygen content interfered with insect movement, feeding, and respiration. Vacuum storage in flexible bags could be a suitable method for pest prevention of sufficiently dry stored products even if a moderate infestation had already occurred.

Key words: Control, Grain quality, Moisture content, Pest prevention, Vacuum

During storage of grain, nuts, pulses or other harvested goods there is a risk that pest insects will infest the product. This may cause considerable loss. Hermetic bags are an advantage for dry products but hermetic storage may lead to molds if moisture contents are high or increase due to the respiration of pests. Besides, such bags may be punctured by hatching beetles, weevils or last-instar larvae of moths in search of a pupation site before the oxygen inside the bag is consumed. It may therefore be useful to apply a vacuum to reduce residual oxygen content at the beginning of the hermetic grain storage. Other authors have reported the potential of hermetic or vacuum grain storage (Navarro and Donahaye, 1985; Navarro et al., 2002; Villers et al., 2006). In a project on pest-proof long-term grain storage (Adler et al., 2012; Adler and Ndomo-Moualeu, 2013, 2015) we intended to investigate the following questions:

1. What effect has vacuum storage on wheat (*Triticum aestivum* L.) grain of different moisture contents?
2. What effect has vacuum storage on this grain with varying levels of moisture if the oxygen content at the start of the storage is reduced by flushing with nitrogen?
3. Do adult granary weevils, *Sitophilus granarius* L. survive vacuum storage and can they puncture the plastic liner?
4. How does a moderate infestation of granary weevils influence grain quality under vacuum storage?
5. Could vacuum storage be a viable alternative for long-term storage of grain?

MATERIALS AND METHODS

A total of 200 vacuum bags were procured and a machine to draw a vacuum was rented out from

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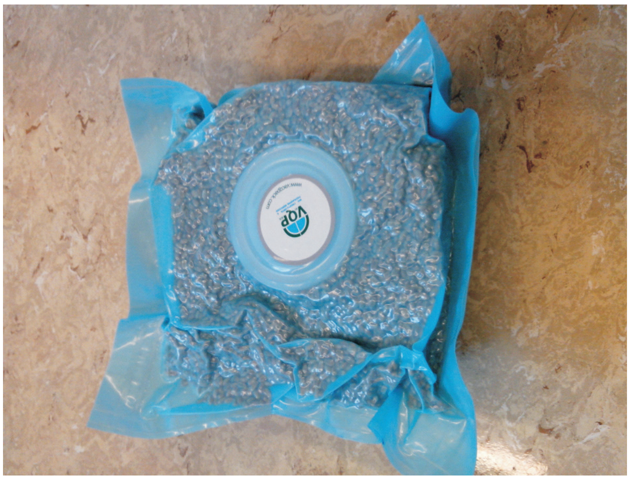

Fig. 1. Sample of 1,300 g wheat grain in vacuum package

Vacqpack Company, from the Netherlands. Granary weevils came from a culture at 20 ± 1°C and 65 ± 5% r.h. kept at the Julius Kühn-Institut Berlin. Thirty young adult weevils at up to two weeks after hatching were counted into glass vials, irrespective of sex and then placed into a bag with wheat grain that had been stored at different relative humidities to reach the grain moisture content of 9.5, 12.5, 14, and 15.5%.

After adding weevils the bags were sealed. Seven days after placing weevils onto the grain, a vacuum of 0.5 bar (50 kPa) was drawn (Fig. 1).

In other bags a vacuum was drawn, then they were flushed with nitrogen to ambient pressure and again a vacuum was drawn to reduce residual oxygen content to approx. 5%. This procedure was repeated to achieve 2.5% or 1.3% residual oxygen contents, to test the effect of different initial oxygen contents on the survival of weevils and the resulting grain damage. Grain samples were subsequently stored for 3, 6, 12, and 24 months.

After storage, grain samples were checked for residual oxygen contents by taking a sample with a gas syringe and inserting it into a Toray oxymeter. Bags were then opened, the grain checked for surviving weevils and then forwarded to Max Rubner-Institut (MRI) for testing grain quality. For this purpose grain was inspected visually and subsequently tested by a human sensory panel of at least five trained staff comparing the smell of whole grain, grist still warm from the mill, grist in an olfactory glass, and grist in an olfactory glass with some boiling water added. Furthermore, germination rate and germination time

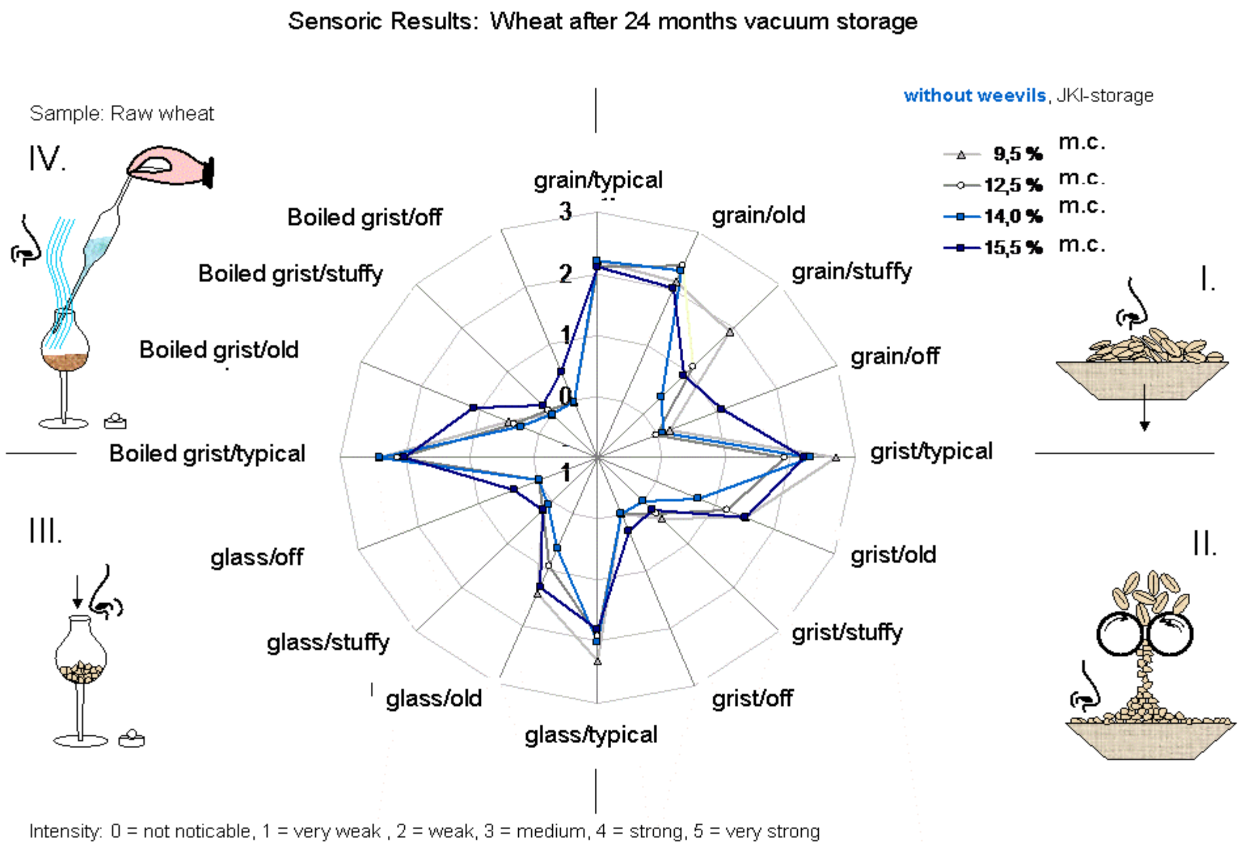

Fig. 2. Sensory results of wheat after 24 months of vacuum storage without weevils

were determined in samples of 100 grains for each of the storage parameters mentioned above.

RESULTS AND DISCUSSION

During experimentation we found the vacuum bags provided did not have an automatically closing valve and as soon as the vacuum was established it needed to be sealed with an adhesive sticker. This may have reduced the reproducibility of our experiments.

The vacuum bags when opened after the shortest storage period of three months did not reveal visible damage caused by granary weevils and no survivors were found. The grain samples were sent to MRI for quality testing. At MRI, one weevil was found alive from the 480 weevils inserted into the bags initially. (30 × 4 different m.c. × 4 different oxygen contents). However, the presence of weevils or residual oxygen content did not affect the grain quality. The main factor determining grain quality was moisture content (Fig. 2).

One result that may be important for grain storage was that at 14% m.c., germination rate was below 90% within six months of storage. In the European Union, grain storage at m.c. up to 14.5% is recommended (Codex Alimentarius, 1995). Together with a reduced germination rate the time required for germination increased from 26 h to 64 h. Based on this finding, it would be advisable to dry grain further if longer storage periods are to be expected. Grain of 12.5% m.c. maintained a high germination rate (Fig. 3) and low germination times. Extremely dry grain (9.5% m.c.) also maintained its germination capacity but developed a slightly 'stuffy' odour (Fig. 2). This could have been caused by oxidation of wheat germ oil in the depth of the grain, while at higher moisture contents the access of air is reduced in grain pores containing more water. Münzing (2013) reported that micro-capillaries of wheat grain are more or less loaded with fine water droplets depending on their moisture content. At extremely low moisture oxygen may enter through these open capillaries and then oxidize parts of the wheat germ or lower regions in the grain leading to a 'stuffy' odour (Fig. 4).

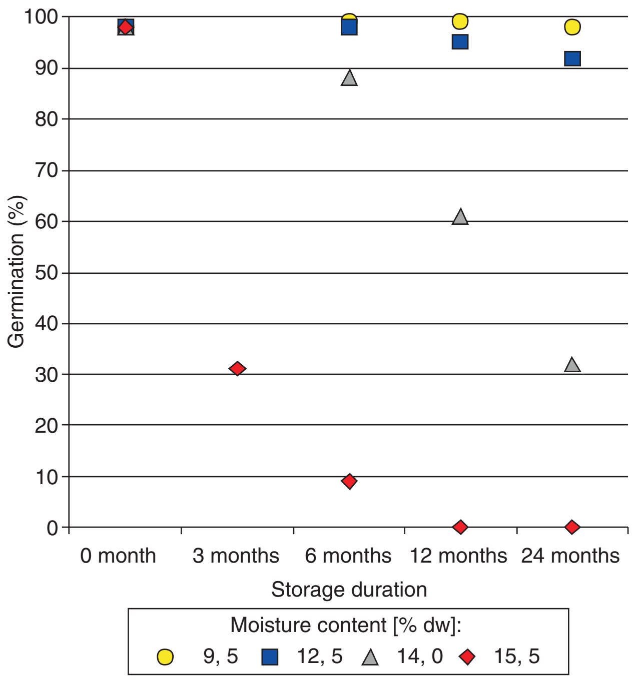

Fig. 3. Germination rate of wheat without weevils stored under vacuum at different moisture contents

Grain of 15.5% m.c. developed a scent described as 'old' and also slightly 'off'. This may have been caused by the higher metabolic activity of the wheat germ leading to exhaustion of some of the energy reserves within the tested grain kernels (Wilkin and Stenning, 1989). Such an interpretation is supported by the observation that oxygen levels in bags with

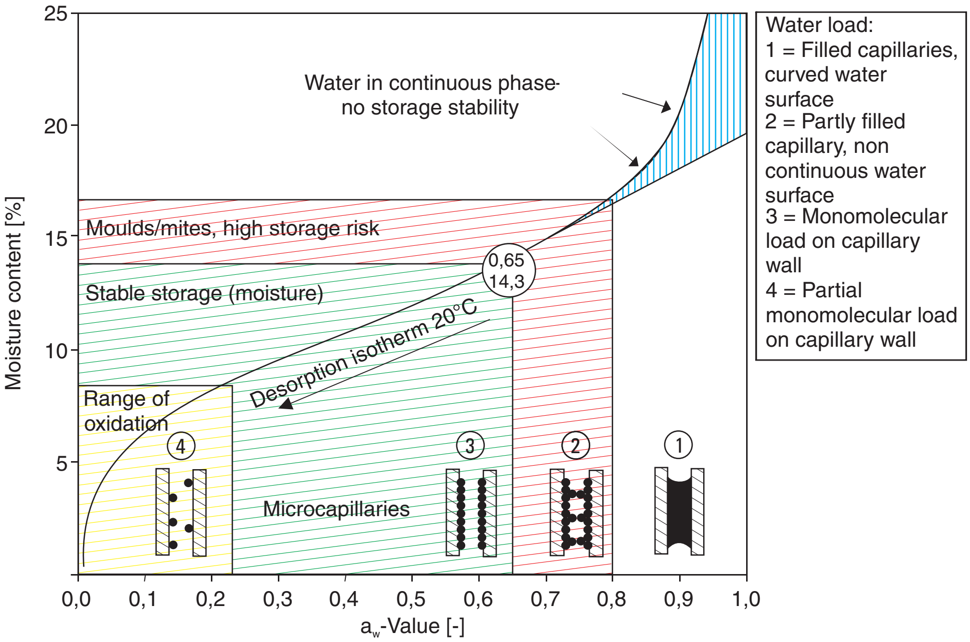

Fig.4. Relevance of micro-capillary water load in wheat grain (modified from Münzing 1995, 2013)

high-moisture grain were always close to zero.

We found little damage caused by granary weevils under vacuum and it is postulated that although only 30 adults and some eggs were present in a bag, the vacuum and insect respiration may have led quickly to critical oxygen levels interfering with insect water production, locomotion, and feeding. Another reason may have been that the flexible plastic liner of the vacuum bag maintained some pressure on the grain making insect movement more difficult (Fig. 1).

CONCLUSION

We conclude that vacuum storage could be valuable for long-term storage of sufficiently dry stored products even if a moderate infestation is already present.

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