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Review paper

HIGHLIGHTS OF PROPER SUNFLOWER SEED STORAGE

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SUMMARY

Sunflower seed storage needs particular care, due to its high fat content, easily cracking shell, exposing the kernel to various alterations, such as germination loss, colonization of fungi and attacks by insects and mites.

Seed moisture content is critical mainly if long-term storage is intended. Proper management of equilibrium between relative air humidity and seed moisture is an essential element, dictating need for seed drying at storage start and frequent aeration during storage.

The main fungi occurring in sunflower seed post-harvest are listed and their involvement in spoilage of this produce is commented; likewise, a comprehensive list of insects and mites detected in Romania and elsewhere in stored sunflower is presented, some of these having definite role in enhancing spoilage.

Measures intended to prevent or control the detrimental factors are briefly exposed, and some special attempts to eliminate these are mentioned.

Key words: Sunflower, breeding, biochemistry, microorganisms, pests, control.

INTRODUCTION

Sunflower growing was particularly successful in Romania during the last three decades. Cropped on roughly half a million hectares, it constitutes in this country the main source of plant oil used in human food.

Breeding of this plant targeted at its beginning to increased yield, by selecting new productive lines and hybrids. In this way new sunflower hybrids created by the Research Institute for Cereals and Industrial Plants, Fundulea, resulted in oil contents raising up to 51-53%.

At present comprehensive research all-over the world is directed to breed sunflower lines and hybrids resistant to a range of severe diseases, commonly affecting this crop.

Still at planting sunflower receives a well-defined destination, either for seed production or industrial purposes. Cropping technologies applied in these two cases, though consistently similar, lay special stress on harvesting healthy seed, free from pathogens, particularly important in those intended for seed production.

Storage of sunflower seed may last for various durations, when this produce is kept for subsequent planting, oil processing or use in confectionery industry. Sometimes storage can involve dehulled meats, devoid of protection afforded by shells (Guenot and Poisson, 1974).

A series of environmental factors, when unproperly managed, could make sunflower seed storage questionable, particularly when long-term keeping is foreseen.

Obviously, the oil factories receive today raw material able to give much higher outputs than in the past, and in the coming years they will process seeds still richer in oil than now.

These circumstances are reviewed in this paper.

Breeding goals

Achieving seed with higher oil content is essentially due to changed quantitative ratio between seed shell and meat, in favour of the latter, while the actual oil amount in meat is augmented to a relatively low extent.

Nevertheless, oil content increases on account of reduced shell percentage, i.e., by its thinning; this fact generates outcomes which are not to be overlooked.

Firstly, thinning shells implies the weakening of their mechanical resistance, hence increased risk of broken seeds and higher percentage of naked seed meats. This phenomenon does not have significant consequences in seed masses with very low moisture contents, since in this case the detrimental biological processes are prevented or merely hampered. However, when seeds are more humid, as in the freshly harvested ones, the naked meats will become very soon favourable substrates for an intense mould development, with all well-known consequences.

At the same time shelled seeds are no more protected from direct contact with atmosphere, thus oxygen easily penetrates in bulk and intensifies seed respiration. Other detrimental issues are changes in free fatty acids content, resulting from exposure to air of increased grain surfaces, thus accelerating spoilage effects on oil content.

Breeding for resistance to major sunflower pathogens, such as those inducing *Alternaria* leaf and stem spot, *Septoria* leaf spot, *Sclerotinia* stalk and head rot, gray mould, etc, necessitates a high degree of unilateral breeding, having little contribution to proper sunflower seed storage.

Biochemistry

It is well-known that an increased accumulation of oil in seeds also assumes intensifying of enzymes participating in its metabolism, and particularly of lipases.

Therefore, whenever, from various reasons, favourable conditions for increased enzymatic activity appear, its consequences can be more marked in seeds rich in oil.

During seed maturation before harvest free acidity of oil gradually decreases, this process also going on in the post-maturation period after harvest, the free fatty acids (FFA) being converted into neutral triglycerids by combining with glycerol. This explains the fact that while in moist seeds of recently harvested heads the oil free acidity, as expressed as indexes of acidity, has values of several mg KOH in 1 g oil in dry, while in healthy seeds properly performing the post-maturation process, acidity reaches values of only 1 mg or even less. Though, if freshly harvested seeds are kept moist and particularly if temperature also remains high or increased, due for instance to their own respiration, then the free oil acidity increases or even reaches rapidly high values, i.e., several mg KOH or even tens of mg in 1 g oil.

It should be stated that this acidifying process is wholly undesirable; nevertheless, it does occur even in freshly harvested seeds whose global humidity is at a level which seems not to allow this performance.

Here it is to note that seed moisture, as measured with heating chamber, moisture meter or any other means, gives only an average value of actual humidity of various seeds composing the sample, which could considerably differ individually. Nevertheless, the moisture level above which the lipolysis process begins to increase is by some 2-3% above the critical limit of seed respiratory activity. Therefore by adjusting the storage conditions in dependence of respiration, it could be ascertained that the risk of an extreme increase of free acidity is also removed.

In parallel with increased respiratory activity, danger of seed oil rancidity also grows; this process is not enzymatic, but purely chemical and consists of air oxygen fixation by the unsaturated fatty acids, especially polyunsaturated ones, such as linoleic acid. It should be noted that neutral glycerids are also exposed to rancidity, however less readily and slowly than FFA, so that avoidance of seed oil acidification considerably reduces risks of rancidity.

Reactions allowing increased lipase activity also stimulate activities of other enzymes occurring in seeds. These enhance protein spoilage by proteases hydrolysing them and causing the occurence of aminoacids. Likewise, the respiratory process induces more intense enzymatic oxidation of glycerids, resulting in the formation of sugars. In consequence to intensified seed respiration and enhanced biological activity of its microflora, seed bulk starts warming and the temperature rises to the point when some complex chemical reactions can take place between free sugars and aminoacids, leading to the formation of some compounds brown in colour. This is the process of seed meat darkening, commonly accompanying rancidity.

Intensified enzymatic activity in seeds with high moisture contents and temperature leads to an increased consumption of oil for respiration, thus resulting in progressive reduction of oil percentage content. Seed oil content usually decreases to a higher extent than increase of the corresponding CO_2 amount developed through respiration (Slusanschi, 1972).

Microorganisms

Some common sunflower pathogens may be carried to store by seeds. So, agents of major sunflower diseases, such as gray mould (induced by the fungus *Botrytis cinerea*), Septoria leaf spot (*Septoria helianthi*), Alternaria leaf and stem spot (*Alternaria helianthi*) and Sclerotinia stalk and head rot (*Sclerotinia helianthi*) penetrate storage facilities after harvest (Lipps and Herr, 1981).

Storability of sunflower seed in respect of microorganisms contamination and particularly fungi was investigated by several authors: Champion and Anselme (1966), Christensen (1971), Moysey (1973), Champion (1973), Champion *et al.*, (1974), Iliescu *et al.*, (1979), Herr and Lipps (1982), Ladsous *et al.*, (1988), Tosi *et al.*, (1988), etc.

Analyses performed on sunflower seed fungal load revealed occurrence of an array of parasitic and saprophytic species, including *Botrytis cinerea, Alternaria* spp., *Trichothecium roseum, Cladosporium herbarum, Plasmopara helianthi, Sclerotinia sclerotiorum, Verticillium albo-atrum, Phoma oleracea* var. *helianthi tuberosi, Septoria helianthi, Alternaria helianthi, A. tenuis, A. alternata, Puccinia helianthi, Fusarium moniliforme, Epicoccum purpurascens, Eurotium* spp., *Microascus* spp., *Chetomium* spp., *Helminthosporium* spp., *Trichoderma viride, Acremoniella atra, Curvularia* spp., *Pullularia* spp., *Rhizopus* spp., etc.

When the seed moisture content (MC %), air relative humidity (RH %) and temperature are high, these species are progressively replaced by typical storage saprophytic fungi, belonging to the genera *Aspergillus* (*A. amstelodami, A. glaucus, A. niger, A. versicolor, A. fumatus*, etc), *Penicillium, Absidia, Mucor* and others, which intensely grow, often causing heating, off-flavour and germination loss (Moysey, 1973; Iliescu *et al.*, 1979; Hulea *et al.*, 1982; White and Jayas, 1993).

Freshly harvested, moist sunflower seed, cracked, shelled or crushed, is highly favourable to mould growth. Positive relationships have been found between presence of these and increase of FFA content in contaminated achenes (Guenot and Poisson, 1974). Post-harvest changes in micromyceta population structure have been investigated in Romania by Iliescu *et al.*, (1979) under controlled laboratory and greenhouse conditions, having as goal to establish long-term evolution of some stored seed fungi.

Study on *B. cinerea* present on seeds showed that at reduced RH (45-50%), 10-15°C temperatures and 7.1% MC, the initial infection of 49.5% dropped to 1.6 after 18 months of storage, while the frequency of attacked plants came down from 31.6 to 0.3%. When RH exceeded 90% infection extended rapidly to the whole bulk, rendering it unable for use, and the attack frequency rose to 95.1%.

Frequency of seeds contaminated with *Alternaria* spp. and stored at 60% RH rose from the initial level of 25% to nearly 90%, after 250 days of storage, while S.

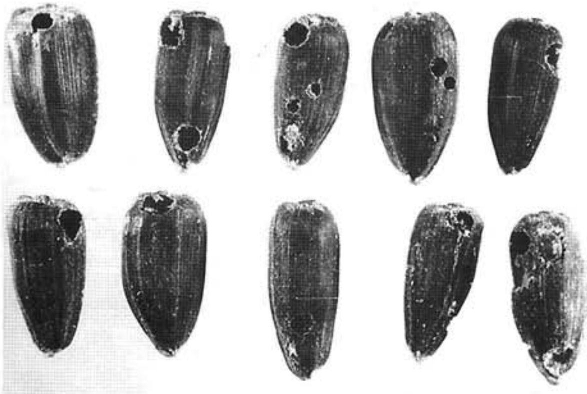

Figure 1. Unhulled sunflower seeds attacked by Lasioderma serricorne F.

Figure 2. Shelled sunflower seeds attacked by Lasioderma serricorne F.

Figure 3. Unhulled sunflower seeds attacked by Plodia interpunctella Hb.

sclerotiorum recorded increase of frequency from 24% to more than 40%. Sharp reduction of *B. cinerea* infection from 40 to less than 10% was noted within 200 days of storage. Slight increases were noticed with *Trichothecium roseum* and *Rhizopus nigricans*, while the saprophytic fungi *Aspergillus* spp., *Penicillium* spp., and *Cladosporium herbarum* showed marked increases in frequency after 250 days.

Mite and insect pests

Piltz (1960) identified insect pests present in oil factories in West Germany. Extensive samplings have been performed in sunflower stores and processing factories in Yugoslavia by Vukasović *et al.*, (1966) and Stojanović and Kosovac (1974), while Atanasov (1974) listed the insects attacking sunflower seed stored in Bulgaria. In Spain, Vargas Piqueras (1979) assessed interactions between five most common insect species found in sunflower seed stores and possible weight losses caused by these.

Recently, Wallace and Jayas (1993) investigated the most important insect and mite pests of stored sunflower seed and their environmental dependence in Canada.

Detailed reports on suitability of stored sunflower seed to feed storage mites are coming from Poland (Czajkowska, 1972) and the former Czechoslovakia (Samsinakova, 1958, Zdarkova, 1967).

In Romania, besides the storage pests found in other countries on sunflower seed, presence of *Lasioderma serricorne* F. (Figures 1 and 2) and *Plodia interpunctella* Hb. (Figure 3) has also been noted (Beratlief, Iliescu, 1990).

Table 1 puts together all these records.

List of mites and insects occurring in sunflower stores is seemingly much more comprehensive, nevertheless the essential pests are included here. None of these are exclusively sunflower pests, most of them originating in other kinds of stored produce kept in the same facilities or in their neighbouring. Feed for these includes a wide variety of seeds or processed products (e.g. *Tribolium* spp., *Oryzaephilus* spp., *Cryptolestes* spp., mites, a.s.o.); others (*Anthicus floralis* L., *Typhaea stercorea* L., *Mycetophagus quadriguttatus* Müll., *Ahasverus advena* Waltl., etc), although not real pests, feed on mould fungi developed on. moist seeds without causing damage to them; their presence is an indicator for unproper storage conditions and critical seed sanitation.

Excessive reproduction of some pest species may lead sometimes to seed heating, resulting in significant losses.

Oilseeds infestation in storage has particular features due to their specific content. Besides germination loss as a result of embryo damage by pests, local temperature raises in seed bulk (heating spots) often exceeding 60-65^{0}C. Reduced thermal conductivity of seeds causes small combustion spots, evolved from insect biological processes, which cannot be dissipated. High temperatures, in their turn, enhance

Table 1: Pests of sunflower seed in storage

Species	Country
Class ARACHNIDA Ord. *Acarina*	
Acarus siro L.	Czechoslovakia
Tyrophagus putrescentiae Schrk.	Poland, Czechoslovakia
Tyrolychus casei Oud.	Poland, Czechoslovakia
Acarus farris Oud.	Poland
Glycyphagus domesticus Deg.	Czechoslovakia, Poland
Carpoglyphus lactis L.	Poland
Aeroglyphus robustus Banks	Canada
Class INSECTA Ord. *Coleoptera*	
Tribolium confusum Duv.	Romania, Germany, Spain
Tribolium castaneum Hbst.	Bulgaria, Romania, Germany, Spain, Yugoslavia
Ahasverus advena Wltl.	Bulgaria, Romania, Germany
Typhaea stercorea L.	Bulgaria, Romania, Germany
Anthicus floralis L.	Bulgaria, Romania, Germany
Oryzaephilus surinamensis L.	Bulgaria, Spain, Yugoslavia, Canada
Oryzaephilus mercator Fauv.	Germany, Spain, Canada
Cryptolestes ferrugineus Steph.	Spain, Yugoslavia
Cryptolestes pusillus Schönh.	Canada
Cryptolestes spp.	Bulgaria
Corticaria elongata Gyll.	Yugoslavia
Melanophthalma distinguenda Com.	Yugoslavia
Coninomus spp.	Yugoslavia
Cryptophagus pseudodentatus Creutz.	Yugoslavia
Mycetophagus quadriguttatus Müll.	Bulgaria
Trogoderma versicolor Creutz.	Yugoslavia
Trogoderma spp.	Germany
Palorus ratzeburgii Wissm.	Bulgaria
Alphitobius diaperinus Panz.	Bulgaria
Carpophilus dimidiatus Fabr.	Bulgaria
Tenebrioides mauritanicus L.	Bulgaria, Germany
Lasioderma serricorne F.	Romania, Germany
Necrobia rufipes Deg.	Germany
Ord. *Hemiptera*	
Xylocoris galactinus Fieb.	Yugoslavia
Xylocoris formicetorum Boh.	Yugoslavia
Ord. *Thysanura*	
Lepisma saccharina L.	Bulgaria
Ord. *Lepidoptera*	
Plodia interpunctella Hb.	Bulgaria, Romania
Cadra cautella Wlk.	Germany

activity speeding up their life cycle, along with increased amounts of heat, which progressively expand throughout the seed bulk and spoil it.

Pest outbreaks in oilseeds can also result in unexpected increase of free fatty acids from smaller particles resulting from insect feeding, the surface exposed to oxidation being thus larger (Eggins and Coursey, 1968).

Tribolium spp. attack is followed by production of uric acid and quinones, their levels being proportional to density of insect population.

Decay induced by increased temperature caused by insect attack can also impair seed organoleptic quality resulting in the occurence of extraneous taste and flavour in oil.

Physical factors

Temperature, seed moisture content and relative air humidity are among the major variables conditioning safe sunflower seed storage.

Temperature determines rates of fungal spore germination and mycelial growth, but also mobility, feeding and reproduction of insects and mites.

Some fungi are psychrotolerant, still growing below 0°C (*Mucor, Penicillium*). Nevertheless, most fungi are mesotolerant, living at temperatures of 5-35°C, optimum development occurring at 20-25°C. Other fungi, termed as thermotolerant, are particularly important to stored products, being able to grow at 20-60°C; among these, *Aspergillus fumigatus, A.niger, A. nidulans, A. oryzae* and *Penicillium arenarium* are relevant examples. These are able to induce spontaneous heating.

Marked temperature increase, resulting in spontaneous heating generates pyrophoric gases, easily inflammable, spontaneously igniting when temperature considerably raises, causing fire, explosions, extensive damage and casualties.

Gradual evolution takes these steps:

- up to 40°C, moulds are rapidly growing, seeds become bitter and rancid, and their flowability is slightly reduced;
- at 40-60°C, tanned seeds with spoiled consistency appear, as well as heavy mould and fermentation smell, whereas seed flowability is greatly hampered, sometimes seeds being totally damaged;
- above 100-120°C, self-ignition is possible.

In Romania it is advised that temperature of stored sunflower seed does not exceed 25°C during April 1 through October 31, and it should be kept below 18°C between November 1 and March 31. This is usually achieved by storage facilities aeration or forced ventilation during cool nights or in cold periods.

Equilibrium moisture content

The equilibrium between grain moisture content and relative air humidity was first established for stored wheat, indicating proper seed storage conditions and start of spoilage activity by fungi, insects and mites. This condition generated the term "water availability", which is usually determined by the water content of a product when placed in store, although it can be altered by interchange of seed moisture with atmosphere, or by accidental rain leakage into the store.

Water availability usually means equilibrium relative humidity (ERH) or "water activity" (a_w). ERH represents the relative humidity of the intergranular air in equilibrium with water in a substrate, while a_w is the ratio of vapour pressure over that of pure water, at constant temperature and pressure. ERH and a_w are numerically the same, but ERH is expressed as percentage while a_w as decimal fraction of one. Water content is easily determined, but it gives vague indication on the availability of water for fungal growth or pest reproduction since the relationship between water content and its availability differs with product.

Equilibrium moisture content/relative humidity is different in whole seeds and various ground-sunflower seed fractions or shelled kernels. This relationship is useful for understanding conditions inducing spoilage by fungi, insects or mites.

Standard seed moisture level 9.5% recommended in Canada (White and Jayas, 1993), and 8%, as advocated in Romania (Gumaniuc *et al.*, 1984) are rarely attained in practice, due to climate conditions at harvest. Therefore, drying seeds is often indispensable prior to putting sunflower seed in storage.

Preventive and control measures

Foreseeing difficulties which could be encountered with sunflower seed storage, some preventive measures are necessary.

Lowering moisture content of produce before storage is essential, taking into account the storage duration. This operation is feasible in a variety of conditions, from solarization of small amounts of seed to thermal treatment in dependable and sophisticated commercial installations. It is essential that temperature during drying should not exceed 60°C, to prevent germination damages. If grain humidity is higher, drying temperature should be lower (Chanet *et al.*, 1974).

Relative air humidity during storage should be kept at about 70% and temperature below 10°C, by continual and properly managed ventilation. Constant temperature is to be maintained in seed bulk, temperature level being checked every 2-3 days in the first weeks of storage, and further at 10-12-day intervals.

Insect and mite contamination should be suppressed without delay when noticed, using conventional fumigants (e.g., methyl bromide, phosphine, etc). This treatment is to be performed by trained personnel, according to safety regulations of the concerned country.

Attempts have been made to control moulds caused by fungi in stored sunflower. In Romania, Filipescu *et al.*, (1963) tested sunflower seed storage under anaerobic conditions, combined with chemical treatments. Among the compounds tested, thiourea at 1% applied to seeds containing 18% moisture yielded good results, affording suitable protection for 3-4 months. Likewise, sodium azyde (NaN_3) at 0.2% and paraformaldehyde 2 ‰ were also efficient in sealed stores.

Other attempts to prevent mould spoilage with propionic acid or its salts gave erratic results, their efficacy showing a wide variety of responses.

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ASPECTOS SOBRE UN ADECUADO ALMACENAMIENTO DE LA SEMILLA DE GIRASOL

RESUMEN

El almacenamiento de semilla de girasol necesita de un cuidado particular, debido a su alto contenido de aceite, la facilidad de reptura exponiendo la almendra a varias alteraciones tales como pérdida de germinación, colonización de hongos y ataques de insectos y ácaros.

El contenido de humedad de la semilla es critico principalmente si se prevé un largo almacenamiento. Un manejo adecuado del equilibrio entre la humedad de la semilla es un elemento esencial, concluyéndose la necesidad del secado de semilla al comienzo del almacenamiento y ventilación frecuente durante el almacenamiento.

Los principales hongos que frecuentan la semilla de girasol en la postcosecha son descritos y su implicación de los daños que producen son comentados, de la misma manera una lista comprensiva de insectos y ácaros detectados en Rumania y en cualquier parte en semilla de girasol almacenada es presentada, teniendo algunos de ellos un papel definitivo en incrementar los daños.

PRINCIPAUX FACTEURS POUR UNE BONNE CONSERVATION DES GRAINES DE TOURNESOL

RÉSUMÉ

Le stockage des graines de tournesol requiert une attention particulière, liée à la teneur élevée en matière grasse, à la facilité de décorticage, exposant l'amande à diverses altérations telles qu'une baisse de la germination, une colonisation par des moisissures et des attaques par les insectes ou les mites. Le taux d'humidité est essentiel si la conservation à long terme prévue. La gestion rationnelle de l'équilibre entre l'humidité relative de l'air et celle de la graine est un élément principal, déterminant la nécessité soit d'un séchage de la graine au départ du stockage ou de fréquentes ventilations en cours de conservation.

Les principaux champignons présents sur les graines de tournesol après récolte sont listés et leur implication dans l'altération du produit commentée, une liste de l'ensemble des insectes et mites répertoriés en Roumanie et ailleurs, durant le stockage du tournesol est présentée, plusieurs d'entr'eux ayant un rôle précis dans l'augmentation des dégâts.

Les mesures prévues pour la prévention ou le contrôle des facteurs préjudiciables sont brièvement exposées et certaines tentatives pour les éliminer sont mentionnées.