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Quality of peanuts, walnuts, pistachio's and raisins

A review of optimal storage conditions

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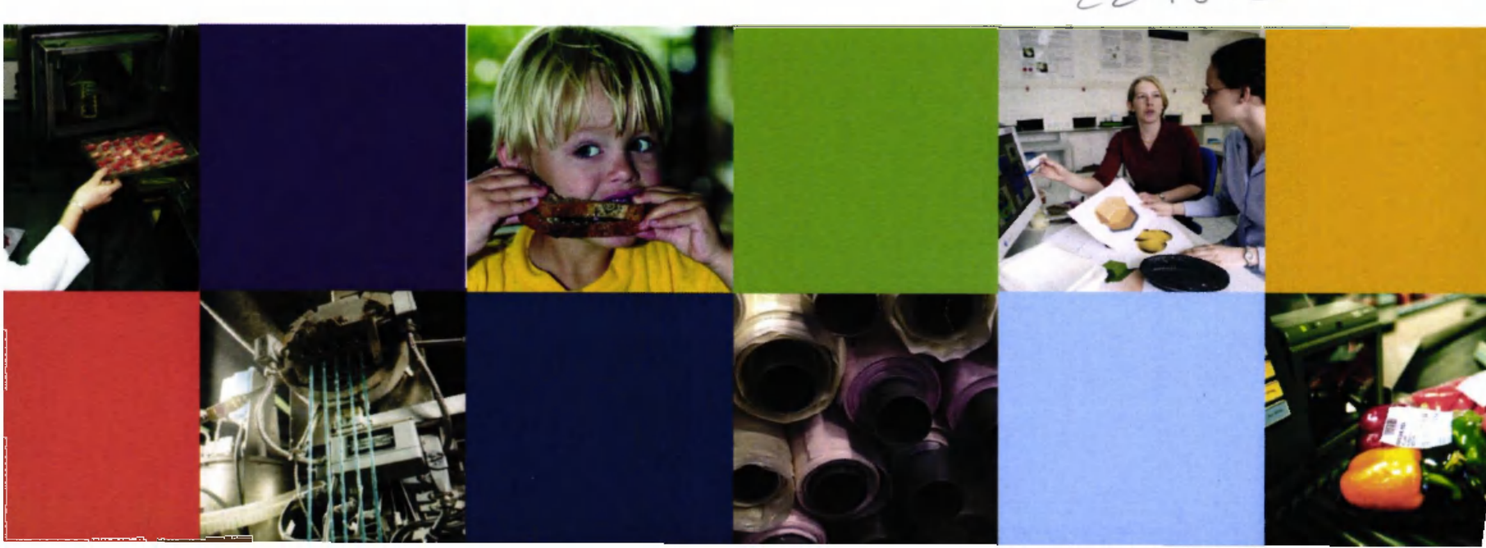
Report 1429



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Abstract

Storage conditions in Intersnack warehouses are 10-12°C and 50-70% RH. They are a result of many years of experience and good practice. Nevertheless Intersnack is interested in a more scientific based advice whether current or other (modified) conditions are optimal. It may be necessary or allowed to change conditions, for example 1) to raise the storage temperature (with respect to low energy storage), 2) to limit the storage time or 3) to make the conditions more specific for different nuts like: peanuts, walnuts, pistachio's, and raisins.
A literature search was conducted in the period between August and November 2012. The results can be found in this report. A broad overview of current recommendations for the storage of peanuts, walnuts, pistachio's, and raisins is provided.

A lot of different factors are influencing the quality of nuts and raisins. Starting quality is of major importance for keeping good quality during storage. Therefore it proofed difficult to give cultivar specific recommendations for optimal storage. Scientific literature is quite fragmented, research in which the effect of different storage conditions on such a broad array of quality parameters is evaluated at the same time, is very scarce.

Current storage conditions in Intersnack warehouses in Rotterdam and Doetinchem are 10-12°C and the target relative humidity is between 50% and 70%.

- Most recommendations for peanut and walnut storage temperature are lower (0-10°C), the RH is in the good range. There might be a benefit from CA storage (low oxygen).
- These temperatures fall within the range of recommendations for pistachio and raisin storage. Temperature seems not to be very critical for pistachio and raisins. RH is in the good range.

With respect to product quality it is not advised to raise the storage temperature for peanut and walnut, however in the case of pistachio and raisin it might be possible, but limitations in storage time can be expected.
Specific storage recommendations for Runner peanuts, Kerman pistachios, Chandler walnuts, and Thompson raisins were not found.

Content

1 Introduction

Intersnack is a leading European savoury snack producer group, formed by totally 29 companies, which are located in different European countries. Intersnack's core business is producing private label products but Intersnack is also known for own brands like "Jack Klijn" nuts and dried fruit snacks. Intersnack Procurement B.V. located in Doetinchem (NL) is buying and sourcing globally: nuts, dried fruits, pine and sunflower seeds etc. to supply the relevant Intersnack companies using these raw materials in their final products.
Intersnack is permanently looking for significant volumes of high quality nuts in the market. The crops may have been stored already for longer time in the growing region or are directly shipped after harvest and drying to Intersnack for further storage. It is unknown what the difference is in deterioration between new crop and end of crop.
In order to supply year-round, spreading risks and stabilize prices Intersnack has two major storage facilities: one in Rotterdam and one in Doetinchem. The storage conditions in these warehouses are 10-12°C and 50-70% RH and are a result of many years of experience and good practice. Nevertheless Intersnack is interested in a more scientific based advice if current or other (modified) conditions are optimal. It may be necessary or allowed to change conditions, for example to raise the storage temperature (with respect to low energy storage) or to limit the storage time or to make the conditions more specific for different nuts like: peanuts, walnuts, pistachio's, and raisins.
Intersnack Procurement bv wants to assure that the current storage conditions of these nuts and raisins in Intersnack warehouses are the optimal conditions for maintaining the highest possible quality during long term storage, which may last up to 1-1,5 years.
Food & Biobased Research, part of Wageningen UR performed a literature study into the optimal storage conditions of these products. Food & Biobased Research is a contract research organization and offers applied research and development for clients in the food sector.
The aim of the study was to collect and analyze all relevant (public available) knowledge concerning the selected products and topics. This report is the result of the science based findings.

Focus of the literature study

Phase 1: Selection of products.

The following products will be included in the literature study:

a. raw peanuts, runner type with skin from Argentina (packaging: breathable big-bags),
b. raw peanuts, runner type without skin (blanched) from Argentina (packaging: breathable big-bags)
c. raw pistachio nuts, Kerman variety in the shell from USA (packaging: breathable big-bags),
d. raw shelled USA walnuts, Chandler type (packaging: vacuum bag in carton),
e. raisins natural, Thompson medium USA (packaging: carton with PE liner, not sealed)

Selection criteria were based on the following aspects: economic value; stability of peanuts, pistachio's, walnuts and dried fruits during storage; speed of deterioration (taste, rancidity); others such as amount of publications, scientific level of the publications.

Thus, the pre-selection is made for the following reasons:

- *Blanched Argentine peanuts are chosen, as this is the biggest commodity*
- *Blanched Argentine peanuts are relatively sensitive for deterioration.*
- *Skin peanuts are chosen, as this is the second biggest commodity, (probably) less sensitive in comparison with blanched peanuts.*
- *Pistachios are chosen as a relatively stable product (probably the most stable tree nut).*
- *Walnuts are chosen for its known high sensitivity. Highest of all tree nuts.*
- *Raisins Thompson medium are chosen as it is the biggest commodity of dried fruits .*

Phase 2: Screening, listing and summarization of available knowledge on quality decrease (sensorial/chemical/microbiological) of the above mentioned products in relation to the storage conditions.

- Sensorical changes: texture, odour, colour and taste
- Chemical changes: free fatty acids (ffa), peroxide value, anisidine value, others
- Microbiological changes: probability of microbiological growth in relation with storage conditions. Focus is on mycotoxin forming mould species, such as *Aspergillus parasiticus* and *Aspergillus flavus* which may produce aflatoxin.

Relevant storage conditions included in the study are:

- 6-12 °C (RH range 40-80%)
- 13-19 °C (RH range 40-80%)
- 20-26 °C (RH range 40-80%)
- 27-33 °C

This report is structured as follows. Chapter 2 gives insight in how the literature search is performed. Chapter 3 gives a short overview of various aspects that are important for the storage quality of nuts and raisins, while the following chapters focus more in detail on the selected nuts, and where possible the selected variety. Therefore peanuts (Runner type) are described in Chapter 4, pistachios (Kerman variety) are presented in Chapter 5, walnuts (Chandler type) are described in Chapter 6, while raisins (Thompson) can be found in Chapter 7. A discussion and conclusion of the findings can be found in Chapter 8.

2 Methods

The literature search was conducted in the period between August and November 2012.
The search of scientific papers was performed using the Scopus and PubMed databases:

- Scopus is a large, multidisciplinary bibliography of over 14000 journal titles from 4000 publishers providing access to over 25 million abstracts going back to 1966.
- PubMed comprises more than 20 million citations for biomedical literature from Medline, OldMedline (before 1966), life science journals, and online books.

The search strategy used in these databases, is based on the following words:
TITLE-ABS-KEY(((peanut AND runner) OR (pistachio AND kerman) OR (walnut AND chandler)) AND (storage OR postharvest OR quality))
TITLE-ABS-KEY((raisin OR raisins) AND (thompson) AND (postharvest OR storage OR quality))
In order to obtain review articles the filter of the corresponding databases was used (review, systematic review).

Furthermore, grey literature (reports and information from websites) was selected by browsing websites and news items from various organisations, e.g.

- European Commission (EC),
- European Food Safety Authority (EFSA),
- Food and Agriculture Organization (FAO),
- Sydney Postharvest Laboratory (SPL),
- Transport Information Service (TIS),
- States Department of Agriculture (USDA),
- UC Davis Postharvest Technology Center.

3 General considerations

Quality indices that are used to describe *nuts* are (Mitcham et al. 2012):

- colour;
- texture (crispness);
- flavour: development of staleness and rancidity;
- moisture content;
- incidence of decay-causing fungi;
- insect damage.

Nuts in the shell have longer storage potential than shelled nuts. Broken pieces are more perishable than halves or whole kernels.

Maintenance of quality and storage life of nuts depends on their *moisture content* and the *relative humidity (RH)* in storage; *temperature* in storage; the exclusion of *oxygen* (O_2) and effective insect control (Kader et al. 2002). Assuming insect control to be in order before storage of nuts at Intersnack warehouses, the first aspects will be discussed shortly in the following paragraphs. These aspects have a great influence on product quality, have a strong interrelationship and most often can not be regarded separately. In the last paragraph of this chapter mycotoxins, and especially aflatoxin will be discussed. General composition of peanuts, pistachios, walnuts and raisins is presented in Appendix 1.

3.1 Moisture content and relative humidity (RH)

The relation between the moisture content of nuts and the relative humidity of storage rooms can be described by moisture sorption isotherms. A moisture sorption isotherm is a curve giving the relationship between humidity and equilibrium water content of a material for a constant temperature[1]. Moisture sorption isotherms for Franquette walnuts and Kerman pistachios are shown in figure 3.1.
Moisture content of some specific nuts at T=21°C and a_w=0.2 to 0.8 is 2.2-8.2 (pistachio) and 2.8-7.0 (walnut) (Kader et al. 2002).

Next to moisture content and RH water activity is important, especially in relation to the nuts' susceptibility to fungal attack, including mycotoxin producing species such as *Aspergillus flavus* and *A. parasiticus*.
The relationship between air RH and water activity (a_w) of nuts can be described as follows:
$a_w = 0.01 \times RH$
when RH is in equilibrium with nut moisture content (Kader et al. 2002).

[1] *http://en.wikipedia.org/wiki/Isotherm*

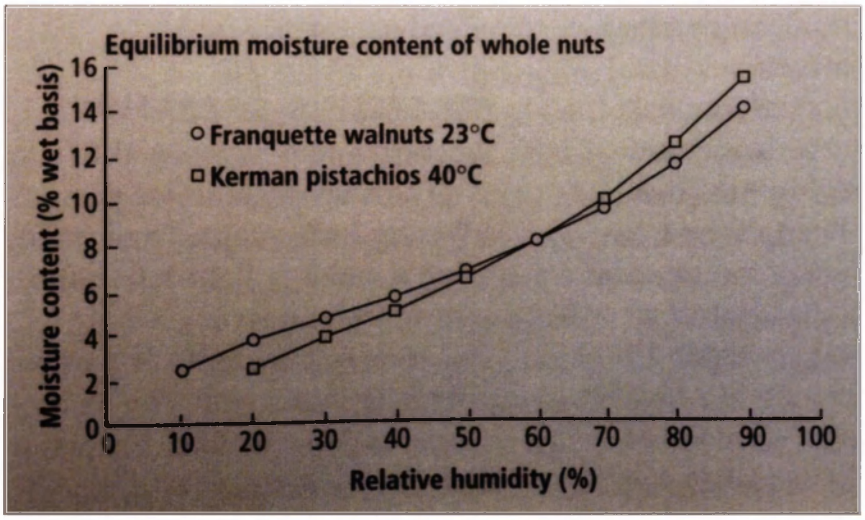

Figure 3.1. Relation between moisture content (on fresh weight basis) and ambient RH at indicated temperatures for pistachio and walnut (Kader et al. 2002).

3.2 Temperature (T)

Several quality aspects are related to temperature. The relation between moisture content and equilibrium RH is temperature-dependent. Furthermore, lower temperatures reduce mould growth and deterioration, such as lipid oxidation (which results in rancidity). The lower the temperature, the longer storage life (Kader et al. 2002).

Fat decomposition, which has a negative effect on flavour and taste, may proceed by hydrolytic/enzymatic fat cleavage or by oxidative fat cleavage. Hydrolytic/enzymatic fat cleavage is described below, oxidative fat cleavage is described in the paragraph 3.3.
If the critical water content of nuts is exceeded, hydrolytic/enzymatic fat cleavage is promoted. Fat-cleaving enzymes are activated by the elevated water content. The additional action of light and *heat* may accelerate this process. Free fatty acids sometimes have an unpleasant odour and taste. During extended storage peanuts may become rancid.
The free fatty acids formed are consumed by respiration processes in nuts to form carbon dioxide and water, a process which is associated with considerable evolution of heat.
The consumption of fatty acids by respiration processes is associated with a considerably greater evolution of heat than is the case with the respiration equation for carbohydrates. The spoilage process proceeds in a type of chain reaction, because heat and water are formed by the fatty acids consumed by respiration, which in turn contribute to an intensification of the process. This leads not only to a reduction in the utility value of the nuts (rancid odour and taste) but this also has a qualitative and quantitative effect on oil yield. Hydrolytic/enzymatic fat cleavage and respiration may be limited by low temperatures (TIS 2012a), (TIS 2012b), (TIS 2012d).

3.3 Oxygen (O_2)

In addition to proper temperature management low oxygen levels (below 0.5%) are beneficial to maintaining flavour quality and for insect control. Exclusion of oxygen (O_2) usually is performed by vacuum packaging or by packaging in nitrogen (Kader et al. 2002).

As mentioned in the previous paragraph, fat decomposition may proceed by hydrolytic/enzymatic fat cleavage or by oxidative fat cleavage. During oxidative fat cleavage (in which oxygen is involved), food components react with atmospheric oxygen in spoilage reactions. Atmospheric oxygen may enter into an addition reaction with unsaturated fatty acids through the simultaneous assistance of light, heat and certain fat companion substances. Rancidity caused by oxidative fat cleavage is particularly noticeable in the case of shelled nuts, because the shelling process results to a certain degree in exposure to atmospheric oxygen. It is therefore essential to store nuts in the dark and to protect them from oxygen and metal parts, since otherwise they become brown-coloured and develop a rancid odour and taste (TIS 2012a), (TIS 2012b), (TIS 2012d).

3.4 Mycotoxins

Aflatoxins can be found as a result of fungal contamination with *Aspergillus flavus* or *Aspergillus parasiticus* at both pre- and post-harvest in the following food commodities: ground nuts (e.g. peanuts), tree nuts (e.g. almonds, hazelnuts, pistachios, brazil nuts, cashew nuts, walnuts, pecan nuts), dried fruit, spices, figs, crude vegetable oils, cocoa beans, maize, rice, cottonseed and copra. The degree of contamination depends on temperature, humidity, soil and storage conditions for the crop (EFSA Panel on Contaminants in the Food Chain (CONTAM) 2009).
As a rule, aflatoxin is only found in individual nuts. If batches intended as a human foodstuff are affected by this toxin, the product can no longer be approved for human consumption, limits are givenbelow. Nuts affected by aflatoxin cannot be distinguished with the naked eye from the other nuts in a batch. The toxin may be detected using UV light (TIS 2012a), (TIS 2012b), (TIS 2012d). Water activities above 0.70 at 25 °C are 'unsafe' as far as growth of *Aspergillus flavus* and *Aspergillus parasiticus* and possible aflatoxin production are concerned, relative humidity should therefore be kept below 70% and temperatures between 0 and 10 °C are optimal for minimizing deterioration and fungal growth during long time storage (Joint FAO WHO Food Standards Programme 2004).

Exposure to aflatoxins from all sources should be as low as reasonably achievable, because aflatoxins are genotoxic and carcinogenic (EC 2010). Maximum levels of aflatoxins are laid down in Commission Regulation 1881/2006 (EC 2006) and are amended by in Commission Regulation 165/2010 (EC 2010). Limits are given for the total aflatoxin content of food (sum of aflatoxins B1, B2, G1 and G2) as well as for the aflatoxin B1 content alone, because aflatoxin B1 is by far the most toxic compound (EC 2006). Products exceeding the maximum levels should not be placed on the market in the EU. In table 3.1 maximum levels of aflatoxins in nuts and dried fruits

are presented. A distinction is made between products that still need to be sorted, and productss intended for direct consumption. Maximum levels may differ for different nut species.
In 2008, the Codex Alimentarius set a maximum level of 10 μg/kg total aflatoxins in ready-to-eat almonds, hazelnuts, and pistachios at a level higher than that currently in force in the EU (4 μg/kg total aflatoxins) [2]. Recently the European Commission and Member States have aligned EU legislation for these nuts with the Codex Alimentarius decision. Currently, discussions will take place to align the new proposed maximum levels for all tree nuts.

Table 3.1. Maximum levels of aflatoxins in nuts and dried fruits (EC 2010).

Foodstuffs	Maximum levels of aflatoxins (μg/kg)			
	before sorting or physical treatment [a]		for direct consumption [b]	
Aflatoxins	B1	Sum of B1, B2, G1 and G2	B1	Sum of B1, B2, G1 and G2
1 Groundnuts (peanuts) and other oilseeds*	8.0	15.0	2.0	4.0
2. Almonds, pistachios and apricot kernels	12.0	15.0	8.0	10.0
3. Hazelnuts and Brazil nuts	8.0	15.0	5.0	10.0
4 Tree nuts, other than the tree nuts listed in 2. and 3.	5.0	10.0	2.0	4.0
5. Dried fruit	5.0	10.0	2.0	4.0

[a] to be subjected to sorting, or other physical treatment, before human consumption or use as an ingredient in foodstuffs
[b] intended for direct human consumption or use as an ingredient in foodstuffs
* with the exception of groundnuts (peanuts) and other oilseeds for crushing for refined vegetable oil production; crude vegetable oils destined for refining; and refined vegetable oils

[2] *http://www.efsa.europa.eu/en/topics/topic/aflatoxins.htm*

4 Peanuts, Runner type

Strictly speaking, peanuts are not true nuts, but geocarpic legumes (which means legumes that grow underground). Thanks to their high oil content, they have quite the same characteristics as nuts. Peanuts are transported both shelled and unshelled. As a legume with a high protein content (24 - 35%), the peanut is one of the world's most important staple foods after wheat (TIS 2012a).

4.1 Advised storage conditions

General recommendations for the storage of peanuts are provided in table 4.1, where an overview is presented of the storage conditions advised by different organisations.

Table 4.1. Recommendations for the storage of peanuts.

Product	Temperature (T)	Relative humidity (RH)	Responses to Controlled Atmosphere (CA)	Reference
Dried fruits and nuts	Optimum: 0-10°C [1]	Optimum: 55-70% [2]	$O_2 < 1\%$ [3]	UC Davis Postharvest Technology Center (Mitcham et al. 2012)
Shelled (roasted) peanuts [4]	Optimum: 0°C (with temperature at set point 0.5°C)	Optimum: 60-70%	$O_2 < 0.5\%$	Sydney Postharvest Laboratory and Food Science Australia (SPL and FSA 2001)
Raw shelled peanuts [5] dried to about 7.5% moisture	10°C: up to 10 months	55-70%	Low O_2 or high CO_2 [6]	USDA Agricultural Research Service (Maness 2005)
Peanuts (shelled / unshelled)	Summer: may be stored for two weeks Winter: several months	65%		Transport Information Service (TIS 2012a)

[1] The lower the T the longer the storage-life. Some products can be stored frozen at -18°C for a year or longer and remain in good condition.

[2] Depending on the moisture content of the products (ranging from 2 to 20%); Equilibrium RH should be identified and used to maximize storage-life. Packaging in moisture-proof containers is recommended.

[3] Oxygen levels below 1% are very effective in delaying rancidity, staleness, and other deterioration symptoms. Either oxygen levels below 0.5% (balance nitrogen) and/ or carbon dioxide levels above 80% in air can be effective in controlling stored-product insects and may provide an alternative to chemical fumigation. Packaging using vacuum or nitrogen flushing to exclude oxygen is recommended to maintain product quality.

[4] At optimal T and RH storage for 360 days is possible.

[5] Seed may be stored at ambient T for up to 11 years with good viability if seed moisture content is < 3.3%. High losses in milling quality may occur if peanuts are dried to below 7% moisture or if kernel T is below 7°C during shelling. Quality of raw shelled peanuts can be maintained for at least 1 year at 1 to 5°C with moisture contents <

7%, or for 2 to 10 years at -18°C and < 6 % moisture. Maintaining RH between 55 and 70% at 1 to 5 °C will maintain peanut moisture content at 7 to 7.5%. Careful handling of peanuts equilibrated to < 5°C is necessary to prevent bruising and subsequent oil seepage from damaged cells within the cotyledon. Upon removal of raw shelled peanuts from refrigerated or frozen storage, equilibration to ambient temperature should be gradual in conditioning rooms, with RH/temperature/air-flow adjusted to prevent moisture condensation onto peanuts.

6 Low O_2 storage is promising for delaying rancid flavour development and insect infestation. High CO_2 storage appears to limit growth of *Aspergillus flavus* in short duration storage of high moisture, non-cured peanuts. Peanuts at 20% moisture stored at 0.6 to 3°C in a high CO_2 environment had acceptable quality for 4 days, but deteriorated after 8 days of storage. For longer term storage of high moisture, shelled peanuts under ambient temperature conditions, O_2 < 1.5% were required to slow *Aspergillus flavus* growth, but no CA totally eliminated aflatoxin production

4.2 Quality aspects

4.2.1 General

Raw peanuts should be surrounded by a tan, pink or red- coloured seed coat that fully encapsulates the seed, and the interior colour of each half-seed should be ivory.
Moisture content for in-shell peanuts should be < 10% to prevent mould growth.
Prior to shelling, peanuts should contain 7 to 10% moisture to reduce splitting and kernel breakage during milling.
Peanuts marketed without seed coats (blanched) should have an ivory coloured raw kernel.
Peanuts are most commonly consumed following roasting that may be accomplished in-shell or after shelling. Roasted peanut kernels should be light-yellow in colour, free of external oil, contain < 6% moisture and be free of dark-coloured kernels (Maness 2005).
Transport Information Services advises the following: the favourable travel temperature range is 5 - 25°C, and to ensure storage stability it is important to comply with the limit values for the water content of peanuts (shelled or unshelled 4-10%) (TIS 2012a).
According to the Codex Alimentarius maximum moisture content for peanuts in-pod is 10%, and for peanut kernels 9.0% (Joint FAO WHO Food Standards Programme 1995). Lower moisture limits should be required for certain destinations in relation to the climate, duration of transport and storage.

4.2.2 Sensorical changes

Improper curing of peanuts results in loss of quality and off-flavour development. Freezing temperatures occurring during harvest while peanuts are still windrowed, or curing at too high a temperature resulted in fermented, fruity off-flavour. Effects of improper curing are greatest on smaller seed, perhaps indicating greater effect on immature seed (Maness 2005).
It is essential to store peanuts in the dark and to protect them from oxygen and metal parts, since otherwise they become brown-coloured and develop a rancid odour and taste (TIS 2012a).
According to the Codex Alimentarius rancid kernels are defined as those which have undergone oxidation of lipids (which should not exceed 5 meq active oxygen/kg) or the production of free

fatty acids (which should not exceed 1.0%) resulting in the production of disagreeable flavours (Joint FAO WHO Food Standards Programme 1995).
Nuts should be protected for odour transfer as well. Because of their high lipid content nuts can easily absorb odours from external sources. Thus, they should not be stored with other commodities that have strong odours (Mitcham et al. 2012). Furthermore, nuts are very sensitive to ammonia damage which causes blackening of external tissues (Mitcham et al. 2012).

Flavour and quality of peanut and peanut products are largely functions of lipid chemistry. Peanuts contain about 50% oil. Palmitic acid (16:0), oleic acid (18:1), and linoleic acid (18:2) are the major fatty acids in peanuts and may comprise more than 90% of the total fatty acids. A high ratio of oleic to linoleic acids (O/L) has been associated with greatly enhanced shelf life and decreased rancidity of roasted peanuts (Andersen et al. 2002).

4.2.3 Chemical changes

As mentioned in the previous paragraph, fatty acid composition of peanut oil is predominantly oleic and linoleic acid, found in roughly equal amounts, and making up 80% of total fatty acids. Certain genotypes may contain substantially more oleic than linoleic acid, with ratios as high as 40:1 (oleic:linoleic). Peanuts with a high oleic:linoleic acid ratio are less susceptible to oxidative deterioration and off-flavour development caused by oxidative cleavage of polyunsaturated fatty acids. The ratio of oleic to linoleic is influenced primarily by genotype, but interactions exist between genotype and the environment (Maness 2005).
Andersen evaluated the effect of an early-, mid-, or late-season planting date on the fatty acid chemistry of four high oleic acid, one mid oleic acid, and five normal oleic acid peanut genotypes over a three year period. Year had a highly significant effect ($P < 0.001$) on the eight main fatty acids, iodine value, ratio of unsaturated to saturated fatty acids (U/S), and percentage of saturated fatty acids. Therefore, data were analysed separately by year. Genotypic effects were highly significant each year, and planting date influenced oil chemistry in two of three years. These strong *year x planting date* and *year x genotype* interactions underscore the importance of year to year variations in oil chemistry and how planting date and genotype can influence yearly variation (Andersen et al. 2002).
Branch determined the fatty acid variation among U.S. Runner-type peanut cultivars. The following cultivars were investigated: Florunner, Sunrunner, GK-7, Southern Runner, Sunbelt Runner, Okrun, and Langley. Significant year and cultivar differences were found within the fatty acid profiles. Southern Runner had the best oleic to linoleic ratio and iodine values; whereas Florunner, Sunrunner, and Langley were the highest in unsaturated and lowest in saturated and long-chain fatty acids(Branch et al. 1990). Changes in fatty acid composition as a result of storage were not investigated.

4.2.4 *Microbiological changes*

As already mentioned in paragraph 3.4 the name aflatoxin refers to four metabolites found in contaminated nuts (aflatoxin B1, B2, G1 and G2). Aflatoxins B1 and B2 are metabolites of *Aspergillus flavus* and all four aflatoxins may be produced by *Aspergillus parasiticus*. A fifth mycotoxin which is somewhat less toxic than aflatoxin and is produced by *Aspergillus flavus*, other Aspergillus species, and several species of Penicillium, is cyclopiazonic acid (Maness 2005). Infection of peanuts can begin before harvest, especially under rainy and humid conditions, and when nuts have insect damage. Fungus-infected nuts are usually removed during the sorting operation to prevent aflatoxin production and contamination that could make the product unfit for sale. The best way to prevent fungal growth on harvested products is to maintain the optimum range of temperature and relative humidity throughout the handling system (Mitcham et al. 2012).

Peanut moisture contents higher than 10% should be avoided to prevent mould growth. Peanuts are susceptible to infection by various moulds and fungi, and a combination of storage at 1 to 5°C and reduction of moisture content below 7.5% may be effective in reducing mould and fungi growth in storage (Maness 2005).

Costa de Camargo investigated the effect of gamma radiation as an alternative for industrial-scale conservation of peanuts. In-shell peanuts were the best feedstock. In-shell and blanched peanut samples (cv. IAC-Runner 886) were subjected to doses of 0.0, 5.2, 7.2 or 10.0 kGy, stored for a year at room temperature and monitored every three months. To investigate the effects of irradiation and storage, determinations of mycotoxic fungi, water activity, colour, fatty acid composition, total phenolic content and ABTS free radical scavenging activity were carried out. Gamma-irradiated blanched peanuts (5.2–10.0 kGy) did not present potentially aflatoxin producing fungi. This result is in good agreement with earlier findings, were 5.2 kGy was a suitable dose for fungi disinfestation in peanuts. Gamma radiation cannot prevent recontamination; therefore, it is always necessary to protect gamma-irradiated products from recontamination sources. Insects are known to be vectors of mycotoxin-producing fungi. Low doses of gamma radiation (0.2–0.8 kGy) are also efficient for killing and sterilizing insects (disinfestation of food) (Costa de Camargo et al. 2012).

4.3 Conclusion on storage conditions

Current storage conditions in Intersnack warehouses in Rotterdam and Doetinchem are 10-12°C and the target relative humidity is between 50% and 70%. Table 4.1 shows that most recommendations for peanut storage temperature are lower (0-10°C), RH is in the good range. There might be a benefit from CA storage (low oxygen).

With respect to product quality it is not advised to raise the storage temperature for peanut, otherwise limitations in storage time can be expected.

Specific storage recommendations for Runner peanuts were not found.

5 Pistachios, Kerman variety

The pistachio tree is dioecious, therefore orchard plantings must include the appropriate ratio of females and males (8:1 in older plantings, but up to 25:1 in more recently established orchards). At present the California industry is dominated by one male cultivar ('Peters') and one female ('Kerman'), although other cultivars are being tested (Labavitch 2005a).
Pistachio nuts are shell fruit (nut types). Because of their high oil content, their requirements regarding care during storage and transport are the same as those of oil-bearing seeds/fruits (TIS 2012b).

5.1 Advised storage conditions

General recommendations for the storage of pistachios are provided in table 5.1, where an overview is presented of the storage conditions advised by different organisations.

Table 5.1. Recommendations for the storage of pistachio nuts.

Product	Temperature (T)	Relative humidity (RH)	Responses to Controlled Atmosphere (CA)	Reference
Dried fruits and nuts	Optimum: 0-10°C [1]	Optimum: 55-70% [2]	$O_2 < 1\%$ [3]	UC Davis Postharvest Technology Center (Mitcham et al. 2012)
Dried pistachio nuts	20°C: up to a year	65-70%		USDA Agricultural Research Service (Labavitch 2005a)
Dried pistachio nuts	0-10°C		Low O_2 or high CO_2 [4]	USDA Agricultural Research Service (Labavitch 2005a)
Pistachio		65-70%		Transport Information Service (TIS 2012b)
Roasted and salted pistachio nuts	cool: storage up to 3 weeks	Dry, well ventilated		Transport Information Service (TIS 2012b)

[1] The lower the T the longer the storage-life. Some products can be stored frozen at -18°C for a year or longer and remain in good condition.

[2] Depending on the moisture content of the products (ranging from 2 to 20%); Equilibrium RH should be identified and used to maximize storage-life. Packaging in moisture-proof containers is recommended.

[3] Oxygen levels below 1% are very effective in delaying rancidity, staleness, and other deterioration symptoms. Either oxygen levels below 0.5% (balance nitrogen) and/ or carbon dioxide levels above 80% in air can be effective in controlling stored-product insects and may provide an alternative to chemical fumigation. Packaging using vacuum or nitrogen flushing to exclude oxygen is recommended to maintain product quality.

[4] Pistachio nuts are relatively stable when stored in air at 20 °C, but storage under high CO_2, reduced O_2 (< 0.5%) and lower T (0 to 10 °C) further improves flavour stability with the added benefit of providing insect control. Vacuum packaging or N_2 flushing of packages also provides benefits. Pistachios are not sensitive to chilling T and can be stored at or below freezing.

Roasted and salted nuts may be stored under cool, well ventilated and dry conditions for up to three weeks and for a little longer in winter. If the maximum duration of storage is exceeded, quality may be impaired, e.g. loss of the brilliant green colour and formation of rancidity (TIS 2012b).
Airtight packaging is ideal because pistachio kernels readily absorb moisture from the air, so becoming limp and because oxygen promotes rancidity (TIS 2012b).
A travel temperature of 0°C is the ideal temperature for achieving the longest possible storage life, but higher travel temperatures (5 - 25°C) are feasible (TIS 2012b).

5.2 Quality aspects

5.2.1 General

Acceptable pistachio nuts must be of sound average quality, dry, predominantly greenish (old nuts are often of a yellowish color), contain no dust or foreign admixtures and have their characteristic odour and flavour. 95 - 98% of nuts in their shell must be open (TIS 2012b).
According to the Codex Alimentarius maximum moisture content for unshelled pistachio nuts is 7.0% (Joint FAO WHO Food Standards Programme 1981b).
Kernel quality criteria include a firm, crisp texture (which is negatively influenced by insufficient drying after harvest or storage at too high a RH), a sweet, oily flavour, and freedom from rancidity (Kader et al. 1982) (Labavitch 2005a).
Composition of various nut species can be influenced by cultivar, cultural practices, climatic conditions, maturity and size (Kader et al. 1982).
Dried pistachio nuts (amongst which Kerman) can be stored at 20°C for 12 months (Kader et al. 1982)

5.2.2 Sensorical changes

Pistachio nuts have a very slight, pleasant odour. If they are transported or stored for an extended period without ventilation, they spoil and release a strong odour (TIS 2012b).
After three months' storage nuts of the Pistacia vera cultivar Kerman were rated higher in firmness and sweetness but lower in crispness, bitterness and rancidity than those of Red Aleppo, Trabonella and Bronte (Kader et al. 1982).

5.2.3 Chemical changes

Fat decomposition may proceed by hydrolytic/enzymatic fat cleavage or by oxidative fat cleavage. The two processes are described par 3.2. and 3.3.
Pistachios are much less prone to rancidification (precipitated by oxidation of polyunsaturated fatty acids, PUFA) than are almonds and, particularly, pecans and walnuts. These nuts also have a high fat content, but their content of PUFA is much higher than of pistachio (Labavitch 2005a).

Tavakolipour examined storage stability of whole split Kerman pistachio nuts (Pistacia vera L.) on samples stored at 5, 15, 25 and 35 °C and a relative humidity range of 11 to 87 percent (Tavakolipour et al. 2010). Peroxide value versus storage time at temperatures 5 and 35°C and different relative humidity are shown in Figure 5.1.a to c. According to Tavakolipour the increase of peroxide value at a given temperature is higher at high and low relative humidity in comparison with medium range RH.
Also, according to Tavakolipour, in a given range of relative humidity, peroxide value increased with increasing temperature, which shows effect of temperature on the rate of lipid oxidation (Tavakolipour et al. 2010). The latter statement I cannot agree with, looking at the values presented at the y-axes in figure 5.1.a and 5.1.b.

Whole split Kerman pistachio nuts

Storage at 5 °C

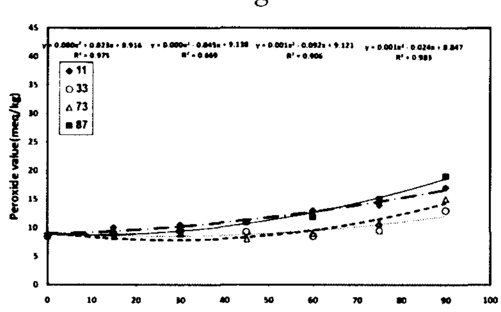

Figure 5.1.a. Peroxide value

Storage at 35 °C

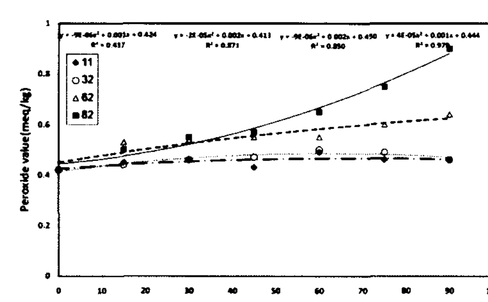

Figure 5.1.b. Peroxide value

Peroxide value of pistachio kernel oils was measured by the iodometric titration method

Whole split Kerman pistachio nuts

Storage at 35 °C

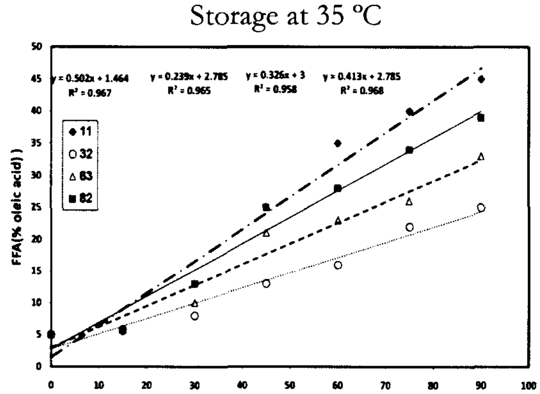

Figure 5.1.c. Free fatty acids

These results led to the following conclusions (Tavakolipour et al. 2010):

- Storage under temperatures 5°C and 15°C and relative humidity ranges 32-33% and 65-70% are suitable conditions for storage of whole pistachio nuts and extend their shelf life.
- Storage under lower temperature (below 10 °C) with the relative humidity range 65-70% is suitable and
- Storage under higher storage temperature (higher than 10 °C) with the relative humidity range 32-33% gives better quality.

5.2.4 Microbiological changes

Aflatoxin production will be influenced by many factors including moisture content, temperature, relative humidity, aeration, insect infestation and other microorganisms, storage time , spore infection density and deteriorative reactions such as oxidation and lipolysis (Tavakolipour et al. 2010). Because mould counts on nuts going into storage can be high, it is important that proper storage conditions (especially low RH, absence of standing water) be maintained to avoid serious problems (Labavitch 2005a).

5.3 Conclusion on storage conditions

Current storage conditions in Intersnack warehouses in Rotterdam and Doetinchem are 10-12°C and the target relative humidity is between 50% and 70%. Table 5.1 shows that these temperatures fall within the range of recommendations for pistachio storage. Temperature seems not to be very critical for pistachio, even at 20°C long-term storage is possible. RH is in the good range.

With respect to product quality raising the storage temperature for pistachio might be possible, but limitations in storage time can be expected.

Specific storage recommendations for Kerman pistachios were not found.

6 Walnuts, Chandler type

Walnuts are shell fruit (nut types), just like pistachios. Because of their high oil content, their requirements regarding care during storage and transport are the same as those of oil-bearing seeds/fruits (TIS 2012d).
The most important aspects of walnut postharvest quality are based on rapid harvest with minimal exposure to field heat, forced-air drying at relatively low temperature, and cold storage at a RH designed to maintain low nut moisture in a reduced O_2 atmosphere (Labavitch 2005b).

6.1 Advised storage conditions

General recommendations for the storage of walnuts are provided in table 6.1, where an overview is presented of the storage conditions advised by different organisations.

Table 6.1. Recommendations for the storage of walnuts.

Product	Temperature (T)	Relative humidity (RH)	Responses to Controlled Atmosphere (CA)	Reference
Dried fruits and nuts	Optimum: 0-10°C [1]	Optimum: 55-70% [2]	$O_2 < 1\%$ [3]	UC Davis Postharvest Technology Center (Mitcham et al. 2012)
Walnut [4]	Optimum: 0-10°C (the lower the better)	50-65%	$O_2 < 1\%$ [3]	USDA Agricultural Research Service (Labavitch 2005b)
Walnut (optimum stability and texture)	10°C	60%	air	USDA Agricultural Research Service (Labavitch 2005b)
Dried walnuts	-3 - 0°C: max 12 months storage	70% [5]		Transport Information Service (TIS 2012d)
Fresh walnuts	-3 - 0°C: storage for a short period			Transport Information Service (TIS 2012d)

[1] The lower the T the longer the storage-life. Some products can be stored frozen at -18°C for a year or longer and remain in good condition.

[2] Depending on the moisture content of the products (ranging from 2 to 20%); Equilibrium RH should be identified and used to maximize storage-life. Packaging in moisture-proof containers is recommended.

[3] Oxygen levels below 1% are very effective in delaying rancidity, staleness, and other deterioration symptoms. Either oxygen levels below 0.5% (balance nitrogen) and/ or carbon dioxide levels above 80% in air can be effective in controlling stored-product insects and may provide an alternative to chemical fumigation. Packaging using vacuum or nitrogen flushing to exclude oxygen is recommended to maintain product quality.

[4] Low water content and high fat content of the kernel make it relatively metabolically stable and able to tolerate low T.

[5] Mould growth threshold is 75%.

Walnut kernels are ideally stored at a water content of 2-3% in packaging which is impermeable to water vapour. Vacuum packaging excludes atmospheric oxygen, which is beneficial in preventing rancidity (TIS 2012d).
Feasible travel temperature: 5-25°C. Storage life of the product is correspondingly reduced at temperatures higher than above the ideal temperature (TIS 2012d).
Walnuts must be protected from freezing (-10°C), because they have a very short shelf life after thawing (Kader et al. 2002).
In-shell walnut kernels derive protection against oxidative changes from the intact shell and kernel skin. Packaging should be moisture-proof. Shelled products should be packaged in airtight, moisture-proof, opaque or foil packages to maximize shelf-life. Unroasted kernels are less likely to take up moisture than roasted kernels (Labavitch 2005b)

6.2 Quality aspects

6.2.1 General

The primary quality criterion is a high oil content (55 to 65% dry weight) that is free of off-flavours caused by oxidation of polyunsaturated fatty acids. Thus, an important criterion is maintaining kernel water content below 4%. Not only does this retard the progression of events that lead to rancidity, it also prevents mould growth and maintains the kernel's crispness. If water content drops too low, however, damage to the kernel's covering can enhance O_2 penetration and rancidity (Labavitch 2005b).
Characteristic indicators of good quality are: large seeds (nuts), thin shell, pleasant flavour (not rancid) and a light shell colour. Walnuts must be free of insect infestation.
The nut shells may become unattractive due to tannin which makes black stains on the outer shell in particular. For this reason, walnuts are sulfur-treated and, now, are bleached only with sodium hypochlorite. Walnuts must be neither rancid nor mouldy and at most 10-15% may be empty (10% of empty walnuts is considered normal) (TIS 2012d).

6.2.2 Sensorical changes

Walnuts have the best colour and flavour when their water content is 2-8%. A higher water content reduces storage life and increases the risk of rancidity(TIS 2012d).
Light-coloured kernels indicates that the kernel still has a relatively long shelf-life (Labavitch 2005b).
Freedom from off-flavours (rancidity) is important (Labavitch 2005b).

6.2.3 Chemical changes

The most serious postharvest physiological disorder that affects walnut quality is rancidity. The problem appears to be caused by poor seed storage conditions; elevated temperature and RH, failure to use CA with reduced O2 concentration (Labavitch 2005b). Fat decomposition may proceed by hydrolytic/enzymatic fat cleavage or by oxidative fat cleavage. The two processes are described par 3.2. and 3.3.

6.2.4 Microbiological changes

Most infections with pathogens are initiated in the orchard and transferred to the postharvest environment. In-shell product is protected unless the shell has been broken or penetrated by insects. The most serious pathogens are fungi such as *Aspergillus flavus* and *A. parasiticus* which can produce aflatoxins that are both toxic and carcinogenic. It is important that damaged kernels be discarded prior to storage and that the low temperature and 50-65% RH be maintained in order to reduce the chance for mould growth. Toxin-producing *Penicillium* sp. have also been found on walnuts (Labavitch 2005b).

6.3 Conclusion on storage conditions

Current storage conditions in Intersnack warehouses in Rotterdam and Doetinchem are 10-12°C and the target relative humidity is between 50% and 70%. Table 6.1 shows that most recommendations for walnut storage temperature are lower (0-10°C), RH is in the good range. There might be a benefit from CA storage (low oxygen).
With respect to product quality it is not advised to raise the storage temperature for walnut, otherwise limitations in storage time can be expected.
Specific storage recommendations for Chandler walnuts were not found.

7 Raisins, Thompson

Raisins are the dried, overripe fruit (dried fruit) of the grapevine, a climbing bush of the grapevine family (*Vitaceae*). Raisin" is a collective term in particular for the following varieties:

- Raisins on the bunch: seeded, large-berried, generally with stalk.
- Sultanas: seedless, large-berried and light yellow. Larger than currants and smaller than raisins.
- Currants: seedless, small-berried, purple/black colour.

(TIS 2012c)

7.1 Advised storage conditions

General recommendations for the storage of raisins are given in table 7.1, where an overview is presented of the storage conditions advised by different organisations.

Table 7.1. Recommendations for the storage of raisins.

Product	Temperature (T)	Relative humidity (RH)	Responses to Controlled Atmosphere (CA)	Reference
Dried fruits and nuts	Optimum: 0-10°C [1]	Optimum: 55-70% [2]	$O_2 < 1\%$ [3]	UC Davis Postharvest Technology Center (Mitcham et al. 2012)
Raisins (max 12 months storage)	4-20°C [4] or 7°C	65% [5] 50-60%		Transport Information Service (TIS 2012c)
Sultanas (max 12 months storage)	4-20°C [4] or 7°C	65% [5] 50-60%		Transport Information Service (TIS 2013b)
Currants (max 12 months storage)	4-20°C [4] or 7°C	65% [6] 50-60%		Transport Information Service (TIS 2013a)
California Raisins [7](in original package)	below 7.5°C	Optimum: 45- 55%		California Raisin Marketing Board (CRMB 2012)

[1] The lower the T the longer the storage-life. Some products can be stored frozen at -18°C for a year or longer and remain in good condition.

[2] Depending on the moisture content of the products (ranging from 2 to 20%); Equilibrium RH should be identified and used to maximize storage-life. Packaging in moisture-proof containers is recommended.

[3] Oxygen levels below 1% are very effective in delaying rancidity, staleness, and other deterioration symptoms. Either oxygen levels below 0.5% (balance nitrogen) and/ or carbon dioxide levels above 80% in air can be effective in controlling stored-product insects and may provide an alternative to chemical fumigation. Packaging using vacuum or nitrogen flushing to exclude oxygen is recommended to maintain product quality.

[4] At T below 10°C, mite growth is inhibited. 4-20°C refers to the favourable travel temperature range.

[5] At RH over 70%, raisins/sultanas become tacky, grow mould and ferment and may support yeast growth. At RH below 60%, raisins/sultanas become tough and hard.

[6] At RH over 65%, currants become tacky, tend to ferment and become mouldy. At RH below 50%, currants become tough and hard.

[7] Natural (sun-dried) Seedless raisins include the Thompson seedless and other newer cultivars such as Fiesta, Selma Pete and DOVine. California Raisins may be stored at room temperature without noticeable loss of colour or flavour for a few months. If the storage room T exceeds 10°C, the RH should be kept below 55%.

7.2 Quality aspects

7.2.1 General

Quality indices that are used to describe *dried fruits* are (Mitcham et al. 2012):

- colour;
- texture (chewiness);
- flavour (sweetness, acidity, sulphur residue, off flavours);
- moisture content;
- incidence of decay-causing pathogens;
- insect damage.

The lower the moisture content the longer the postharvest-life. Pieces of cut fruits deteriorate more rapidly than fruit halves.

The best storage conditions for California Raisins are (CRMB 2012)

- In a controlled atmosphere. Raisins will retain colour, flavour and nutritional value for up to five months if stored, in a dry place with a constant temperature below 7.5 °C and a RH less than 45-55%.
- Otherwise, to maintain optimum freshness, keep raisins sealed in an airtight container in the refrigerator or in your coolest storage area.
- Raisins keep well for longer periods of time if frozen. They also thaw quickly at room temperature.

Water activity(a_w) at 25°C and 13-15% moisture of California Raisins is 0.51-0.56 (CRMB 2012)

7.2.2 Sensorical changes

Some dried fruits, such as raisins, figs, prunes, dates, and persimmons are subject to sugaring on the surface or within their flesh. Incidence and severity of sugaring increase with storage temperature and time. Sugar spotting is a crystallization of sugars under the skin and in the flesh; it may be reversed by gentle heating (Mitcham et al. 2012).

Ammonia can cause darkening of dried fruits (Mitcham et al. 2012).

According to the Codex Alimentarius maximum moisture content for raisins is 19% (seeded, or seeds removed style) or 18% (all other styles and/or types) (Joint FAO WHO Food Standards Programme 1981a).

7.2.3 Microbiological changes

Production of mycotoxins due to fungi is also a concern for raisin production, especially for field drying and during storage in less optimal places. Aflatoxins are produced by the fungi *Aspergillus flavus* and *A. parasiticus* which proliferate in conditions of high relative humidity and room temperature therefore elevated temperature (20-30°C) and high humidity must be avoided, while ventilation through raisins is very important to prevent fungi formation (Mencarelli et al. 2005).

7.3 Conclusion on storage conditions

Current storage conditions in Intersnack warehouses in Rotterdam and Doetinchem are 10-12°C and the target relative humidity is between 50% and 70%. Table 7.1 shows that these temperatures fall within the range of recommendations for raisin storage. Temperature seems not to be very critical for raisins, however cold storage is very well possible. RH is in the good range, but CRMB advises that if the storage room temperature exceeds 10°C, the RH should be kept below 55%.

With respect to product quality raising the storage temperature for raisins might be possible, but limitations in storage time can be expected.

Specific storage recommendations for Thompson raisins were not found.

8 Discussion and conclusions

The quality indices that are used to describe peanuts, pistachios and walnuts are the same. These are the following: colour; texture (crispness); flavour: development of staleness and rancidity; moisture content; incidence of decay-causing fungi; and insect damage.
For dried fruits, such as raisins, most of the same quality indices are used, only development of staleness and rancidity is not an issue, while texture focusses on chewiness instead of crispness.

Flavour, taste, fatty acid composition and off-flavour caused by rancidity are very much linked to each other and a lot of research is performed to these aspects and especially fatty acid composition.
Throughout the literature, reports indicate that the fatty acid compositions of nuts vary significantly by genotype/cultivar, seed maturity, production year, use of fertilizer, soil type, geographical location of production, environmental factors, storage conditions (light, temperature, and humidity), and seasonal effects, among others (Alasalvar et al. 2011).

Oxidation of fatty acids can be prevented by antioxidants, and this fact raised a lot of interest in the naturally present phytochemicals in the various nuts.
Tree nuts contain an array of phytochemicals including carotenoids, phenolic acids, phytosterols and polyphenolic compounds such as flavonoids, proanthocyanidins (PAC) and stilbenes, all of which are included in nutrient databases, as well as phytates, sphingolipids, alkylphenols and lignans, which are not. These phytochemical classes are shown in Figure 8.1. Phytochemical content of tree nuts can vary considerably by nut type, genotype, pre- and post-harvest conditions, as well as storage conditions (Bolling et al. 2011).

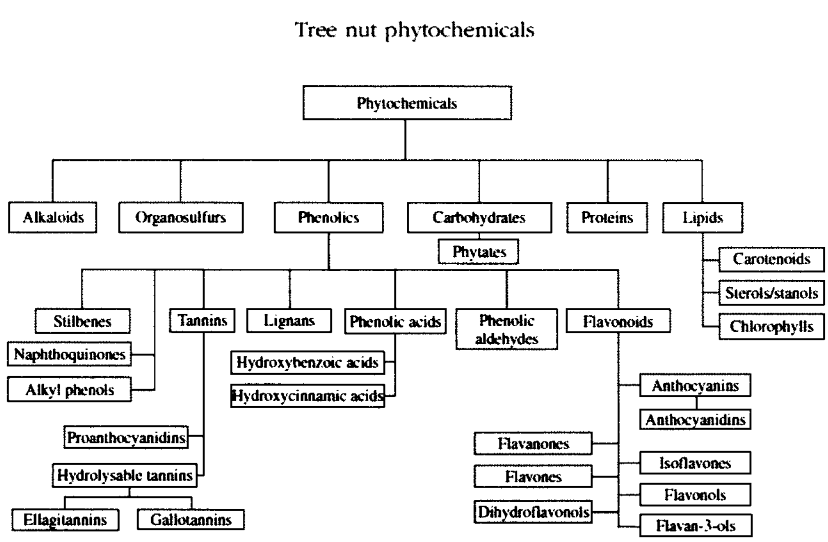

Figure 8.1. Phytochemical classes. (Bolling et al. 2011)

Phytochemical contents may vary as well extensively between and within nut genotypes. Variables imposed before (intrinsic) and after (extrinsic) harvesting contribute to this variation. While the tree nut genotype contributes to the majority of pre-harvest variation in nut phytochemical content, environmental stresses including starvation, infection, predation and UV light also modulate the capacity for phytochemical synthesis. Some particular phytochemicals are influenced by processing (roasting, irradiation and pasteurisation) and storage (temperature and duration) after nuts are harvested. Data for these factors vary among tree nuts (Bolling et al. 2011).

This indicates that a lot of different factors are influencing the quality of nuts and raisins. Starting quality is of major importance for keeping good quality during storage. Therefore it is difficult to give cultivar specific recommendations for optimal storage. Scientific literature is quite fragmented, research in which the effect of different storage conditions on such a broad array of quality parameters is evaluated at the same time, is very scarce.

Current storage conditions in Intersnack warehouses in Rotterdam and Doetinchem are 10-12°C and the target relative humidity is between 50% and 70%.

- Most recommendations for peanut and walnut storage temperature are lower (0-10°C), the RH is in the good range. There might be a benefit from CA storage (low oxygen).
- These temperatures fall within the range of recommendations for pistachio and raisin storage. Temperature seems not to be very critical for pistachio and raisins. RH is in the good range.

With respect to product quality it is not advised to raise the storage temperature for peanut and walnut, however in the case of pistachio and raisin it might be possible, but limitations in storage time can be expected.
Specific storage recommendations for Runner peanuts, Kerman pistachios, Chandler walnuts, and Thompson raisins were not found.

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Appendices

Appendix 1. Composition of peanuts, pistachio nuts, walnuts and raisins[3].

Product	Type	Processing	Water (g/100g)	Protein (g/100g)	Carbohy-drate (g/100g)	Total lipid (fat) (g/100g)	Total SFA (g/100g)	Total MUFA (g/100g)	Total PUFA (g/100g)	total dietary fiber (g/100g)
Peanuts	all types	raw	6.5	25.8	16.1	49.2	6.8	24.4	15.6	8.5
Peanuts	Spanish	raw	6.4	26.2	15.8	49.6	7.6	22.3	17.2	9.5
Peanuts	Valencia	raw	4.3	25.1	20.9	47.6	7.3	21.4	16.5	8.7
Peanuts	Virginia	raw	6.9	25.2	16.5	48.8	6.4	25.3	14.7	8.5
Peanuts	all types	dry-roasted*	1.6	23.7	21.5	49.7	6.9	24.6	15.7	8.0
Peanuts	Spanish	oil-roasted*	1.8	28.0	17.5	49.0	7.6	22.1	17.0	8.9
Peanuts	Valencia	oil-roasted*	2.1	27.0	16.3	51.2	7.9	23.1	17.8	8.9
Peanuts	Virginia	oil-roasted*	2.2	25.9	19.9	48.6	6.3	25.2	14.7	8.9
Pistachio	-	raw	3.9	20.3	27.5	45.4	5.6	23.8	13.7	10.3
Pistachio	-	dry-roasted*	1.9	21.0	29.4	44.8	5.5	23.7	13.4	9.9
Walnuts	English	-	4.1	15.2	13.7	65.2	6.1	8.9	47.2	6.7
Walnuts	black	dried	4.6	24.1	9.9	59.0	3.4	15.0	35.1	6.8
Raisins	seeded	-	16.6	2.5	78.5	0.5	0.2	0.0	0.2	6.8
Raisins	seedless	-	15.4	3.1	79.2	0.5	0.1	0.1	0.0	3.7
Raisins, golden	seedless	-	15.0	3.4	79.5	0.5	0.2	0.0	0.1	4.0

* without salt;

SFA=saturated fatty acids; MUFA= monounsaturated fatty acids; PUFA=polyunsaturated fatty acids

[3] *U.S. Department of Agriculture, Agricultural Research Service. 2012. USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl*