Concerns for quality maintenance during storage of cereals and cereal products

B.O. Juliano*

Abstract

The changes in grain quality that occur during storage of cereals and cereal products are difficult but important to evaluate and quantify. In addition to seed viability and physical aspects, the following properties (particularly for rice) must be considered.

They include nutritional and acceptability attributes such as:

1. Decreases in vitamin B complex, and in vitamin A for yellow maize and sorghum;
2. Aroma volatilisation and deterioration in aromatic rices;
3. Ageing effects in rice 3–4 months postharvest results in improved milling yields, greater water absorption during cooking, reduced solubles and stickiness for cooked rice, and a slight cream colouration of milled rice;
4. Hydrolytic (lipase) and oxidative (lipoxygenase) rancidity of fats;
5. Stack-burning or yellowing with adverse effects on protein quality;
6. Other reported interactions among nutrients located in discrete particles in the endosperm, such as starch-protein interactions.

Of future concern is the possible expression of genes for disease and insect resistance in transgenic rice plants, such as *Bacillus thuringiensis* coat-protein gene, in the rice embryo/aleurone layer and endosperm. Grains of transgenic rices containing genes for resistance to storage pests and diseases should also be checked for possible anti-nutritional properties.

Introduction

Quantitative losses are more readily assessed than qualitative changes in stored grains. Such quality deterioration reduces processing properties, consumer acceptance, and nutritive value of the grain. In addition, many of these changes are not readily detected visually by the consumer when the grain is purchased.

Changes in dormancy, viability (germination) and respiration rate of grain occurs during storage and are discussed by Wrigley et al. (these proceedings). Deterioration due to rodent, insect and microbial infestation has been reviewed (Pomeranz 1982; FAO 1984, 1993). In addition to physical damage and loss, enzymatic breakdown of grain constituents, particularly starch, protein, and lipids occur. Microbial infestation can result in mycotoxin formation, such as in delayed drying during the monsoon season, and during the parboiling process (Vasanthi and Bhat 1990). But soaking sound rough rice in water inoculated with *Aspergillus parasiticus* did not result in aflatoxin contamination of parboiled rice (Yap et al. 1987), suggesting that contamination probably has to be present in the grain before soaking (Bandara 1985). Aflatoxin is concentrated in the bran-polish fraction of brown rice and is reduced by milling (Ilag and Juliano 1982; O. Vasanthi and Bhat 1990).

Critical Moisture Content and Fissuring

Rough rice has a critical moisture content below which fissures occur: 15–16% for susceptible varieties and 12–14% for resistant/tolerant varieties (Juliano and Perez 1993). The phenomenon is complex, but relates to brown rice translucency (Juliano et al. 1993). The screening method adopted soaks 14% moisture rough rice in water for 3 hours and air-drying before milling (Juliano et al. 1993). Thus, flash drying of wet grain can readily be done to about 20 ± 5% moisture with little danger of fissuring, particularly with tolerant varieties. Fissuring occurs not during drying, but during moisture adsorption stress.

The Satake Engineering Co. (1991) has utilised the resistance to fissuring of high moisture rice by the use of a brown-rice preconditioner that warms and moistens only the surface of the brown rice (softens the aleurone layer) just before milling. Also, the freshly milled rice goes through a pressurised conditioning unit that adds 0.7–1.0% moisture per pass to achieve 15–16% moisture content. Such conditioned milled rice does not crack in cold water during cooking, unlike rice of less than 14% m.c., and results in softer, more sticky cooked rice preferred by Japanese consumers.

Vitamins

All vitamins in cereal grains degrade during storage, particularly at high moisture and temperature. Water-soluble B vitamins degrade slowly during storage (Chikubu 1970: Pomeranz 1982: FAO 1984). In addition, riboflavin and pyridoxine are sensitive to light. The content of B vitamins such as thiamine content of brown rice is reduced by parboiling, but diffuses into the endosperm. Vitamin A in maize and sorghum is light sensitive and also decrease during storage, together with vitamin E, alpha-tocopherol. The Rockefeller Foundation International Program on Rice Biotechnology (1993b) is looking into the potential for carotenoid biosynthesis in rice endosperm as a means to reduce the vitamin A deficiency prevalent among children in tropical Asia. Contributing factors are the low intake of leafy green vegetables and milk. The acceptability of such a yellowish rice will have to be determined, in view of the partiality to well-milled white rice.

Aroma

The major aroma principle in cooked aromatic rice, 2-acetyl-1-pyrroline (Buttery et al. 1983), decreases in milled rice during storage (Laksanalamai 1993). Evacuated laminated polythene/nylon packing better retained milled-rice aroma than polythene packing alone. A second, still unidentified, aroma principle is reported (Brahmachary et al. 1990) that can

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* Institute of Chemistry, University of the Philippines at Los Baños, 4031 College, Laguna, Philippines.

be formed together with 2-acetyl-1-pyrroline by the reaction of proline with fructose or sucrose at 128–135°C in the presence of silica (Sarkar et al. 1992). Aromatic varieties are more expensive than nonaromatic rices and are usually consumed immediately after harvest when the aroma level is still high.

Ageing

Storage of rice for 3–4 months after harvest results in ageing effects or after-harvest ripening that is physicochemical in nature (Juliano 1985: Chrastil 1990a). Five of six enzymes in milled rice were not destroyed with ageing due to accumulation of substrate receptors, except cytochrome *c* reductase (Chrastil 1990b).

Milling and cooking quality

The total and head or whole-grain milled rice yields improve during storage, together with the hardness of the raw grain. On cooking, resulting aged milled rice absorbs more water, expands more and has less dissolved solids in cooking water. The cooked grain also is less sticky or more flaky than freshly harvested rice. Aged rice also has a slight creamy colour. Aged rice is preferred over freshly harvested rice in tropical Asia where consumers prefer intermediate–high amylose rices, but ageing reduces the quality of low-amylose rices preferred in temperate Asia, such as Japan, Korea, and China.

Free sugars and amino acids

Storage also reduces the content of free amino acids, nonreducing sugars (sucrose), and albumin (by denaturation) in rice, and increases reducing sugars (Juliano 1985). Three of the major free amino acids concentrated in the outermost layer of milled rice, glutamate, arginine, and gamma-aminobutyric acid (GABA), contribute to the taste of cooked rice (Matuzaki et al. 1992: Tajima et al. 1993: Saikusa et al. 1994). Soaking milled rice before cooking enhances GABA, free amino acids and malto-oligosaccharides, and decreases glutamate, the substrate of GABA production, due to enzyme activity.

Free Fatty Acids and Carbonyl Compounds

The lipids (fat) of rice located in the spherosomes or fat globules begin to decrease after 6 months of storage while the level of free fatty acids increase (Aibara et al. 1986). Oxidation of the unsaturated fatty acids into carbonyl compounds, aldehydes and ketones, contributes to the stale odour of stored rice, mainly due to hexanal. Furthermore, phosphatidylcholine, a major constituent of the spherosome membrane, is hydrolysed into phosphatidic acid after 6 months of storage, indicating spherosome membrane deterioration or leakiness, allowing triacylglycerols to ooze out and be hydrolysed to free fatty acids (Aibara et al. 1986). Fat deterioration of milled-rice products may be minimised by using freshly- and well-milled (low-fat) rice. Rice bran has a potent lipase that becomes active on milling. Parboiling denatures the lipolytic enzymes but increases autooxidation due to heat destruction of natural antioxidants (Sowbhagya and Bhattacharya 1976).

Yellow Rice from Stack Burning

Stack burning or heating of wet rough rice due to embryo and microbial respiration results in yellow or discoloured rice (Phillips et al. 1988b, 1989: Yap et al. 1990). Harvested rough rice of high (>20%) moisture content is susceptible to mould growth and heating of the grain (up to 65°C), conditions optimum for yellowing (Phillips et al. 1988b). Yellowing can increase in stored rough rice of <14% moisture content even under optimum storage conditions, if the rice is improperly handled before and during drying. The mechanism is probably nonenzymic browning (Phillips et al. 1988a; NRI 1991) rather than microbial, and it can be induced by heating the grain at 60°C (Yap et al. 1990). The colour of aged rice may involve a similar mechanism. Yellow rice has lower lysine content and lower protein digestibility and net protein utilisation than untreated rice (Eggum et al. 1984).

However, moderately yellow rice does not produce major adverse effects when fed to rats and broiler chicks in nutritionally balanced diets (NRI 1991). Stackburning of maize of less than 12.5% moisture bagged in polypropylene in lieu of jute bags has been reported, nutritionally altering the maize and making it less suitable for milling for food (Tyler 1992).

Interaction Among Nutrients

Aside from degradation, interaction among membrane-bound particulate substances, such as starch in compound granules, phytin in globoids in aleurone protein bodies, and storage protein, glutelin (alkali-soluble) and prolamin (alcohol-soluble) in protein bodies have been reported to occur during aging using solution experiments. Starch–protein interaction, specifically glutelin–starch interaction has been demonstrated in solution to decrease with ageing (Chrastil 1990c). Phytin complexes with glutelin in 5M acetic acid solution (Juliano et al. 1991).

Transgenic Rices

The Rockefeller Foundation's International Program on Rice Biotechnology (1993a) examines potentially useful genes for glutelin and prolamin storage proteins, and genes for improvement of grain storage quality using rice-grain inhibitor of insect protease (oryzacystatin), inhibitors of storage insect alpha-amylase in maize, wheat, and rice, and antifungal proteins in barley seed (Khush and Toenniessen 1991).

The introduction of alien gene(s) into transgenic rices (Rockefeller Foundation 1993a) would also require biochemical screening for possible effects on food quality of the grain (particularly in vegetative tissue, embryo, aleurone layer, and maternal tissue—pericarp, seed coat, and nucellus) of *Bacillus thuringiensis* (*Bt*)toxin for stem borer control, tungro virus coat protein for tungro virus control, antifungal and antiinsect seed proteins, etc. Some of these rice genes have already been demonstrated to be expressed in transgenic tobacco. However, broad-spectrum resistance to *Bt* toxins has been reported (Gould et al. 1992).

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