CHAPTER 2

LITERATURE REVIEW

2.1 Rice Quality Preferences in Various Countries

Quality preferences in various rice-producing countries and even in regions in the same country are so diverse that no one quality attribute is universally accepted. Such diversity is reflected in the quality evaluation in breeding program, postharvest processing and management in those countries. Rice quality attributes in terms of cooking and eating properties change dramatically with its storage after harvest and this phenomenon is called “aging of rice”. Aging phenomenon is desirable in some tropical Asian countries, for example, India, Malaysia, and Thailand, whose people prefer non-sticky and non-pasty cooked rice but in some temperate Asian countries (Japan, Korea and the northern region of China) where people consume japonica rice, aging lowers eating quality of their rice (Juliano, 1985b). Higher head rice content and more translucent rice were also reported to be rice attributes that were preferred by consumers in Bangladesh, Indonesia, Malaysia, Philippines and Thailand (Unnevehr *et al*., 1992). For trading in the world market, rice exporters need to understand these different demands. Efferson (1985) reported that there are six basic rice types demanded by world market: 1) high-quality long grain rice, 2) medium-quality long grain rice, 3) short grain rice, 4) parboiled rice, 5) aromatic or fragrant rice and 6) glutinous (waxy) rice. Among these, aromatic rice has a special place and gains high price in the international market and Thailand exports a large volume of this type of rice (Office of Agricultural Economics, 2008). Based on production area and market demand, KDML 105 is recognized as the most important Thailand’s aromatic rice cultivar. This information indicates that aroma and flavor characteristic of this fragrant rice is accepted and preferred by Asian consumers, and is also of commercial importance. A research conducted in the United States revealed that the most important acceptance factors for Asian consumers living in the United States were cooked rice appearance and aroma, and the imported Thai Jasmine rice was preferred over other rice in that market (Meullenet *et al*., 2001).

2.2 Natural Aging Mechanism in Rice

Changes in physico-chemical properties of rice after harvest depend on rice genetic makeup and storage conditions. Rice aging is a complicated process which involves changes in physical, chemical and biological properties of the rice grain. A mechanism of aging involving lipids, protein and starch had been proposed by Moritaka and Yasumatsu (1972) and schematic model of the aging process is shown in Figure 2.1. Starch, protein and lipids are the main rice grain components which affect cooking and eating qualities. During storage, starch, protein and lipid contents of rice grain remain essentially unchanged, but their structural changes do occur (Zhou *et al*., 2002). Lipids form free fatty acids, which can complex with amylose and carbonyl compounds and hydroperoxides which can accelerate protein oxidation and condensation plus accumulation of volatile carbonyl compounds. Aroma of rice can deteriorate due to loss of aroma compounds and breakdown of rice substances to yield more amounts of off-odor volatiles during storage. There are increases in number of disulfide bond (S-S) and molecular weight of rice protein and its solubility decrease (Chrastil, 1990b; Chrastil and Zarins, 1992). Protein oxidation, together with an increase in the strength of micelle binding of starch, inhibits swelling of starch granules and affects cooked rice texture. Oxidation of ferulate esters of the hemicellulose fraction of cell wall during storage may contribute to cross-linking and increased strength of cell wall during storage (Mod *et al*., 1983). This would contribute to the greater resistance of the grain to disintegration during cooking. Zhou *et al*. (2002) proposed that the release of free phenolic acids alter integrity of the cell wall and at the same time the phenolic acids exert an effect via their antioxidant activity on the formation of free fatty acid that can further complex with amylose during storage. These changes affect the pasting and gel properties, flavour and texture of cooked rice. Rate of aging process is affected by storage management. The factors most influential on changes in chemical, physical and functional properties of rice during storage are moisture content, storage temperature and storage duration (Perdon *et al*., 1997; Pearce *et al*., 2001). The rate and nature of the change is primarily temperature-dependent and quality shifts generally occur faster with increasing storage temperature and grain moisture content.

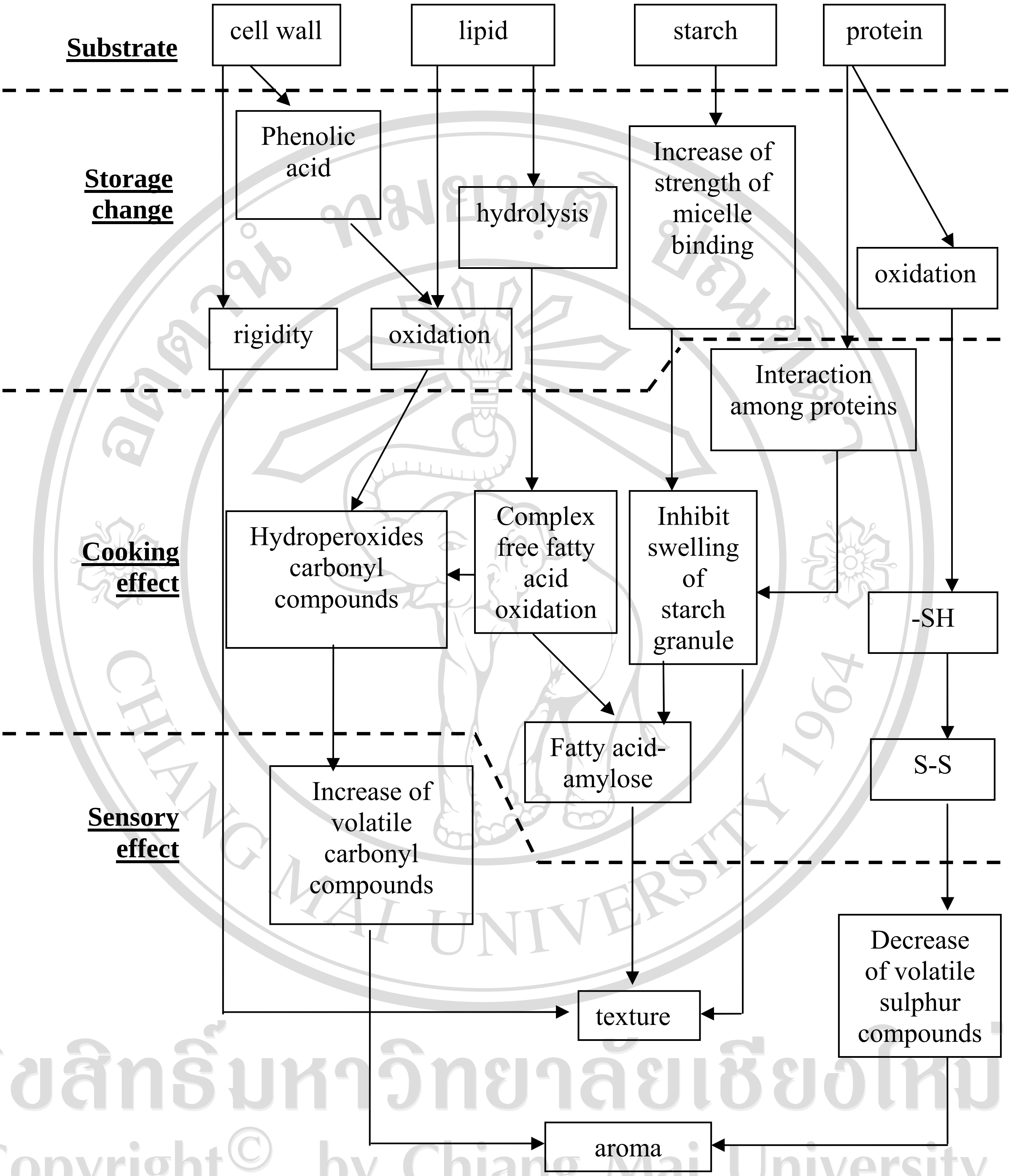

Figure 2.1 Summary of rice aging mechanism model modified from Pomeranz (1992).

2.3 Aging in Relation to Change in Pasting Property of Rice

One of the most sensitive indices of the aging process in rice is the change in pasting properties or viscosity. The viscosity of rice paste increased dramatically after storage of milled and rough rice (Dhaliwal *et al*., 1991; Hamaker *et al*., 1993; Pearce *et al*., 2001; Zhou *et al*., 2003). These changes depended on storage temperature, duration and grain moisture content (Perdon *et al*., 1997; Pearce *et al*., 2001; Zhou *et al*., 2003). The pasting properties of rice flour following storage of the grain for up to 16 months were investigated by Zhou *et al*. (2003). In the study, storage produced changes in the RVA pasting curves of the flour as a variety-, time- and temperature-dependent phenomenon. Pattern of changing of RVA viscograms from samples stored at 4 and 37°C in their study provided a valid comparison of the effects of aging temperature on pasting behavior. The most significant change in the pasting curve was the decrease in breakdown over time and the gradual disappearance of a clearly-defined peak in aged samples. This was attributed to the more organization of rice substances during storage.

Sowbhagya and Bhattacharya (2001) studied on pasting behaviors of fifteen rice varieties belonging to six quality types when stored at room temperature for 51 months storage period. Brabender viscograms were determined at intervals for several slurry concentrations. The progressive viscogram patterns showed several distinctive features: first, the paste breakdown steadily decreased with time of storage; simultaneously there was a steady increase in setback, clearly aging rendered the rice substance progressively more organized and resistant to swelling and disintegration. Second, the changes were relatively rapid at first, gradually slowing down later, but did not show signs of being halted even after 4 years, suggesting that aging of rice probably had no definite endpoint. Third, despite the aging changes, rice of different quality types broadly maintained their inter-quality differences throughout the storage period. Fourth, it is remarkable that the cold-paste:hot-paste viscosity ratio in the samples remained virtually unchanged throughout even while all other viscogram indices changed with storage time.

Change in RVA viscosity of flour from rice cv. KDML 105 during storage as paddy for 6 months at ambient condition was studied (Soponronnarit *et al*., 2008). They reported peak viscosity increase in the initial phase of storage and then decreased in later phase whereas pasting temperature, setback and final viscosity consistently increased in this 6-month study period. Similar changing trend was also found in the studies of other rice varieties (Perdon *et al*., 1997; Fitzgerald *et al*., 2003; Zhou *et al*., 2003) when the viscosity changes were considered in an equivalent storage period. Increase in final viscosity of stored rice was attributed to recrystallization of amylopectin and amylose during cooling of starch paste. This process is called retrogradation which describes the process in which a heated starch paste cools, and the exuded amylose molecules re-associate and unite the swollen starch grains in an ordered structure that results in viscosity increase (Lai et al., 2000). Changes in paste viscosity of stored rice was also reported to be associated with changes in enzyme activities (Dhaliwal et al., 1991) and changes in physico-chemical and structural components of rice starch granule (Martin and Fitzgerald, 2002; Fitzgerald, *et al.*, 2003; Zhou et al., 2002, Zhou et al., 2003) and other cereals as well (McDonough *et al*., 2004). These changes occurred at enhanced rate in higher temperature storage condition (Zhou et al., 2003).

2.4 Aging in Relation to Change in Textural Property of Rice

Rice is usually consumed as a whole grain, so its texture after being cooked is of great importance to rice eater. For people who prefer stored rice, aging improve texture of cooked rice. Cooked rice texture has been defined as a multidimensional characteristic (Szczesniak, 1987) and can be measured by sensory analysis or instrumental methods. However, hardness (also referred to as firmness) and stickiness (also termed adhesiveness) are critical and these texture characteristics govern palatability of cooked rice in Asian markets (Okabe, 1979). Texture of cooked milled rice is affected by many factors such as variety, physico-chemical properties, postharvest handling practices, cooking methods and storage conditions. Storage temperature and duration influenced the texture of cooked milled rice (Tsugita *et al*., 1983; Lima and Singh, 1993). The texture of cooked aged rice was harder and less sticky than cooked freshly harvested rice. Hardness was affected by storage duration and rough rice storage moisture content (Meullenet *et al*., 2000). Cooked kernel hardness decreased with increasing storage moisture content and reached a maximum between 15 and 22 weeks of storage, depending on the rough rice storage moisture content. A significant interaction was found between rough rice moisture content and storage duration. Increasing rough rice moisture contents delayed the perception of maximum hardness (Meullenet *et al*., 2000). These results are in partial disagreement with results published by Champagne *et al*. (1998) who reported no difference in hardness as rough rice moisture content increased. However, Lyon *et al*. (1999) reported that samples dried to 15% MC were less chewy than those dried to 12% MC. In addition, results are in agreement with a study by Tamaki *et al*. (1993) who reported that rice stored at 12% MC was initially found to be harder than rice stored at 15 or 18% MC.

Cooked rice stickiness was greatest in freshly harvested rice and decreased with aging (Chrastil, 1994) or when treated to accelerated aging (Gujral and Kumar, 2003). Storage temperature and duration significantly affected adhesives to lips, an indicator of rice stickiness (R^2 = 0.58). The negative relation between cooked rice stickiness and soluble solid had been reported by Cameron and Wang (2005). Increasing storage temperature decreased rice stickiness (Meullenet *et al*., 2000). Tamaki *et al*. (1993) reported similar results on Japanese rice cultivars using instrumental measurements, rice stickiness measured by instrumental methods decreased consistently during the first 90 days of storage regardless of storage moisture content or storage temperature. In addition, Champagne *et al*. (1998) reported a decrease in adhesiveness with increasing rough rice moisture contents during storage.

2.5 Aging in Relation to Change in Aroma Characteristic of Rice

Aroma of rice plays an important role in consumer acceptability. The aroma in rice is composed of a complex mixture of odor-active compounds and among the compounds identified, 2-acetyl-1-pyrroline, is considered to be highly important (Buttery *et al*., 1988; Jezussek *et al*., 2002). 2-Acetyl-1-pyrroline was first identified by Buttery *et al*. (1982), its chemical structure is shown in Figure 2.2. This compound is responsible for popcorn-like or pandan-like (*Pandanus amaryllifolius*) aroma (as described by Asian consumers) that emanates from cooked aromatic rice, also from uncooked grain (Mahatheeranont *et al*., 2001) and aerial part of the aromatic rice

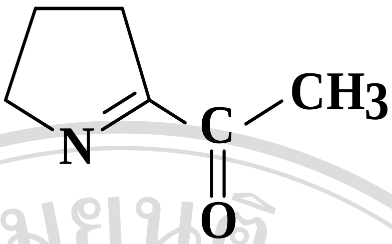

Figure 2.2 Chemical structure of 2-acetyl-1-pyrroline

plant (Yoshihashi *et al*., 2002). Buttery *et al*. (1983a; 1983b; and 1986) indicated that 2-acetyl-1-pyrroline was the most important volatile compound responsible for odor characteristic of aromatic rice and this aroma compound is present in several Asian aromatic rice varieties including the Thai aromatic rice cv. KDML 105.

Reduction of 2-acetyl-1-pyrroline concentration in Thai aromatic rice cv. KDML 105 during storage was reported (Laksanalamai and Ilangantileke, 1993). The concentration of 2-acetyl-1-pyrroline in the freshly harvested aromatic rice was higher than that of the aged one. However, aroma character of a rice variety is conferred by complex of volatile compounds of that rice. To maintain high aroma quality, high quantity of aroma compounds has to be preserved in the rice. Of this particular importance, attempts were made to seek for appropriate measures for stabilization of 2-acetyl-1-pyrroline and other volatile compounds in rice during storage (Widjaja *et al*., 1996a; Wongpornchai *et al*., 2004; Yoshihashi *et al*., 2005). Volatile compounds emanated from cooked (Widjaja *et al*., 1996a; Tava and Bocchi, 1999) and uncooked (Mahatheeranont *et al*., 2001) aromatic rice were investigated. Several volatile compounds found in aromatic rice were identified and quantified, and their contributions to aroma of the rice were verified. Among odor-active compounds identified from food products and from aromatic rice, 2-acetyl-1-pyrroline had the lowest odor threshold value (a minimum detectable level) which indicates the great important contribution of this compound to aroma of the rice, though it is present in small amount (Harrison and Dake, 2005; Yang *et al*., 2008). Hexanal (identified as an off-odor compound in rice) was found to be the most abundant volatile compound in rice (Widjaja *et al*., 1996a; Tava and Bocchi, 1999) but it had high odor threshold value. Major odor-active compounds of aromatic rice, their odor descriptions and odor threshold values are shown in Table 2.1.

In rice industry and commercial system, rice must be stored for lengthy periods of time in forms of paddy, brown and milled rice prior to processing and consumption. During storage, the flavor of rice can deteriorate due to changes in its volatile components by way of several mechanisms. These include breakdown of desirable volatile constituents, losses via diffusion out of the rice into the environment and generation of undesirable volatile compounds. This is of particular importance for fragrant rice in which the unique aroma characteristics rely on the relative proportions of many individual components (Widjaja *et al*., 1996b). Maintenance for aroma character of aromatic rice is dependent on the stability and the levels of individual aroma components that make up its fragrance characteristic. Increases or decreases in concentration of some volatile compounds would affect aroma of rice and the same compound could be either desirable or undesirable odor, depending on its concentration. For example, Widjaja *et al*. (1996a) reported that (*E*)-2, (*E*)-4-decadienal can be desirable when present in low concentration in rice and can be undesirable when its concentration was increased. Investigation of volatile components of uncooked Khao Dawk Mali 105 brown rice by Mahatheeranont *et al*. (2001) revealed that the rice has more than 140 volatile constituents and among these, 70 volatiles were identified including the key aroma, 2-acetyl-1-pyrroline. Storage lowered the amounts of 2-acetyl-1-pyrroline and increased amounts of the off-odor compounds, *n*-hexanal and 2-pentylfuran which affected aroma quality of rice cv. KDML 105. Wongpornchai *et al*. (2004) attempted to define the most appropriate postharvest drying methods for preservation of aroma characteristic of the rice during storage and they recommended that lower air temperature drying method was the most suitable drying method to maintain higher concentration of 2-acetyl-1-pyrroline and lower amounts of *n*-hexanal and 2-pentylfuran.

Oxidation of free fatty acids and lipids to carbonyl compounds is known to be responsible for off-odor development on milled rice. Of these compounds, *n*-hexanal increases actively with storage time and is used as a rancidity indicator in various agricultural stored products. Hexanal in combination with pentanal, alkenals and ketones was reported as a causal component of the off-flavor

Table 2.1 Major odor-active compounds, odor descriptions and odor threshold values of Jasmine rice (Yang *et al*., 2008).

Odor-active compound	Odor threshold in air [a] (ng/L)	Odor description [b]
1-pentanol	153	plastic
hexanal	1.1	green tomato, green
(*E*)-2-hexenal	3.1	green, apple
2-heptanone	3.5	fruity, sweet
heptanal	0.9	floral
2-acetyl-1-pyrroline	0.02	popcorn
benzaldehyde	85	almond
1-octen-3-ol	2.7	mushroom
2-pentylfuran	19	floral, fruit
octanal	0.4	citrus
3-octen-2-one	6.7	rose
(*E*)-2-octenal	2.7	nutty, cooked flour
1-octanol	22	citrus
guaiacol	1.5	black rice-like, smoke
2-nonanone	31	fruity, flora
nonanal	2.6	citrus, fatty
p-menthan-3-one	4.7	mint
(*E*)-2-nonenal	0.09	beany, cucumber
1-nonanol	18	fatty
decanal	2.6	citrus
(*E, E*)-2,4-nonadienal	0.2	nutty, fatty
(*E*)-2-decenal	2.7	fatty
indole	8.1	sour fruit
4-vinylquaiacol	2.8	nutty
(*E, E*)-2,4-decadienal	2.3	fatty

[a] Odor thresholds in air were calculated in relation to the odor threshold of (*E*)-2-decenal on the basis of the detectable minimum concentration of (*E*)-2-decenal and other odor-active compounds.

[b] Odor-active compounds were described by assessors during GC-olfactometry.

of old cooked rice (Tsugita, *et al*., 1983). In milling process, lipid bodies of rice bran layer disrupted and some residual retain on the kernel. This oil-free fatty acid is rapidly oxidized by lipid hydrolysis enzyme or auto-oxidation processes, resulting in the development of the rancid odor compounds in the stored milled rice (Lam and Proctor, 2003). Odor-active compounds such as heptanal, octanal, nonanal, (*E*)-2-nonenal, decanal, and 2-heptanone are degraded from oleic acid, whereas hexanal, pentanol, pentanal, (*E*)-2-octenal, (*E, E*)-2,4-decadienal, and 2-pentylfuran are degraded from linoleic acid (Monsoor and Proctor, 2004). Oxidative rancidity involves a reaction between the lipid and molecular oxygen. The reaction takes place at the double bonds of unsaturated fatty acids and can be accelerated by singlet oxygen, free radicals, metal ions (iron, copper and cobalt), light, radiation and enzymes containing a transition metal prosthetic group such as lipoxygenase (LOX) (Barnes and Galliard, 1991).

2.6 Aging in Relation to Changes in Cooking Property and Color of Rice

Cooking properties of rice such as cooking time, grain expansion (kernel elongation, length-width ratio), volume expansion, water uptake, and loss of solid to cooking water changed dramatically with time of storage. Pearce *et al*. (2001) reported that water absorption and volume expansion ratios of cooked rice increased with storage; and they found that grain moisture content, storage duration and storage temperature influenced the cooking properties of rice. The result agreed with Daniels *et al*., (1998) who reported that water absorption during cooking of rice increased with storage. Increase in water absorption ratio with time of storage of rice stored at high temperature (37°C) was also previously reported by Perdon *et al*. (1997), and they reported that the ratio was increased only in first three months of storage, then leveled off or declined. Cooking time and swelling of cooked rice kernel increased and color of rice changed to be more yellowish during storage of rice. These changes were affected by storage time, temperature and grain moisture content (Chrastil, 1990a). For investigation on storage change in rice cv. KDML 105, Soponronnarit *et al*. (2008) reported increases in water uptake and volume expansion, and reduction of solid loss value and whiteness of rice cv. KDML 105 when the rice was stored as paddy for 6 months in ambient condition. Sirisoontaralak and Noomhorm (2007) found similar result in the study of 12-month storage duration in rice cv. KDML 105 in which *b*-value (yellowness) increased while total solids in cooking water decreased.

2.7 Influence of Aging on Rice Protein Property

Proteins are most concentrated in the outer layers of rice kernel but significant amounts are also present in its endosperm. Total protein does not change considerably during storage but their chemical properties can be altered substantially. Protein influences rice property attributes, especially in paste viscosity (Zhou *et al*., 2003) and texture of cooked rice (Chrastil, 1994; Martin and Fitzgerald, 2002). One mechanism by which protein influences pasting and textural properties is hypothesized to involve the regulation of water diffusion into the starch granule and which consequently alters the water and time requirements for cooking. Researches demonstrated that protein content affects texture, tenderness and cohesiveness of cooked rice, indicating that protein plays an important role in regulating rice textural property. Nevertheless, the mechanism by which protein affects is not clear.

Studies on the influence of protein on rice properties were focused on rice storage glutelins (oryzenin), since it is the main (75-90%) storage protein in rice (Juliano, 1985a). Similar to other cereals, prolamines (1-5%), globulins (2-10%) and albumins (2-5%) are also found in rice (Juliano, 1985a). Oryzenin and oryzenin-starch interaction on rice properties were studied extensively (Chrastil, 1990b; 1992; 1993; 1994; Chrastil and Zarins, 1992; 1994; Zarins and Chrastil. 1992). Oryzenin is composed of subunits that are linked by both intra- and intermolecular disulphide bridges (Sugimoto *et al*., 1986; Chrastil and Zarins, 1994). These subunits are able to form large macromolecule complexes that are stabilized by disulfide bonds and hydrophobic interactions (Utsumi, 1992). During storage of rice, the molecular weight of oryzenin increases significantly (Chrastil, 1990b), which correlates with an increase in disulphide bonding (Chrastil and Zarins, 1992). Formations of disulphide bond of the rice storage protein (oryzenin) decrease solubility of the protein and affect cooked rice texture. By statistical analysis, a research result revealed that functional properties of flour from different rice cultivars were associated with the amount of polymeric proteins and their size distribution (Oszvald *et al*., 1986).

Decrease in solubility was also thought to explain the decrease in stickiness observed in stored rice (Chrastil, 1994).

Influence of protein on aging process was investigated via RVA viscosity measurement as well (Zhou *et al*., 2003). Flour from aged rice was treated with a chemical (beta-mercaptoethanol) to cleave disulfide bond and was also treated with enzyme (protease) to cut the rice protein to small units. The treated aged rice flours produced various changes in the RVA viscograms. The most notable effect was produced by protease treatment which increased peak viscosity and decreased final viscosity of flours from aged (higher temperature storage) rice samples. Aged samples treated in this way showed a peak and trough as normally seen in fresh rice, indicating protein appears as a key component in the aging process. It had also been suggested that starch granule associated with proteins confer strength to the gelatinized granule by reducing the leaching of amylose molecules or by physically holding the starch granule together. Teo *et al*. (2000) reported interaction of oryzenin-starch, as a consequence of changes in structure and properties of oryzenin, could influence starch properties such as swelling and solubility and could be the major factor responsible for rheological changes associated with aging of rice. Stickiness of oryzenin and its mixture with starch decreased during postharvest storage was reported (Chrastil, 1994).

2.8 Formation and Reduction of Disulfide Bond in Rice Storage Proteins

All rice storage protein, such as glutelins (oryzenin), prolamines, globulins and albumins contain cysteine (Juliano, 1985a) which is readily converted to cystine. Figure 2.3 illustrates the conversion of cysteine to cystine by constructing a disulfide bridge. This reaction occurs even under mild oxidation condition. Reduction of cystine to cysteine is possible using sodium borohydride or thiol reagents (mercaptoethanol or dithiothreitol (DTT)). The equilibrium constants for the reduction of cystine at pH7 and 25°C with mercaptoethanol or dithiothreitol are 1 and 10^4, respectively (Belitz and Grosch, 1999). Reduction of a disulfide bond by DTT proceeds in a two sequential thiol-disulfide exchange reaction. Diagram showing a two-step reaction of DTT to reduce cystine to cysteine is presented in Figure 2.4.

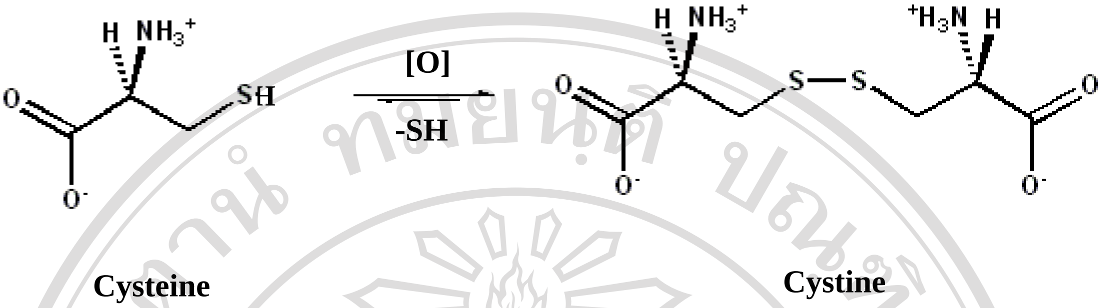

Figure 2.3 Increase of disulfide bond by oxidation of cysteine to cystine.

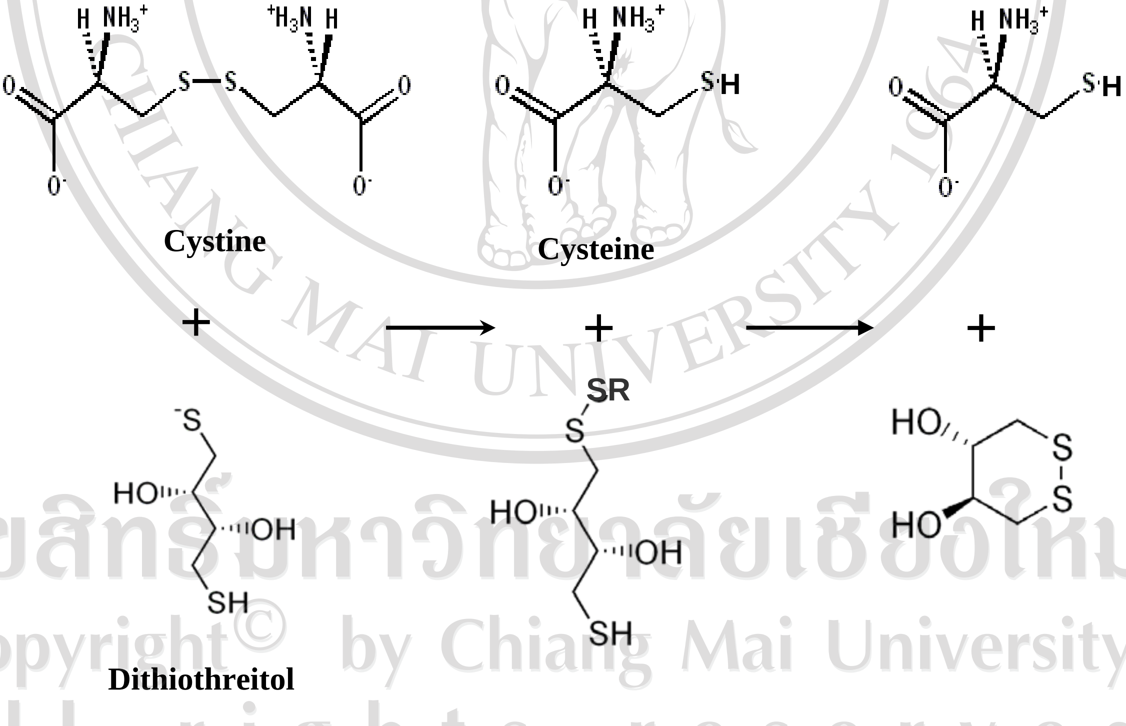

Figure 2.4 Two-step reaction of dithiothreitol (DTT) to reduce cystine to cysteine.

2.9 Accelerated Aging Process on Physico-chemical Characteristics and Quality Attributes of Rice and Other Cereals

Preference for stored rice of Asian consumers is a crucial factor for rice exporters. This is due to the fact that storage requires long period of time, space and is costly, and rice must be supplied to market continually throughout the year after harvest. An attempt called accelerated aging had been reported to enhance rate of aging in rice and could yield rice of having cooking properties comparable to those of naturally-stored rice within a short time (Gujral and Kumar, 2003; Soponronnarit *et al*., 2008). This accelerated aging process could also modify rice physico-chemical characteristics that are related to quality attributes of the freshly harvested rice. Review of literatures reveals that the factors involved in the accelerated aging process are temperature, heating duration and grain moisture content. Gujral and Kumar (2003) steamed paddy rice at three different grain moisture contents and found the increases in kernel elongation and width expansion, water uptake and cooking time and decrease in solid loss of cooked rice. Texture parameters of the cooked rice such as hardness, cohesiveness and springiness also increased and adhesiveness decreased which resulted in better eating quality comparing to that of freshly harvested rice. However, this study did not report on head rice yield and color of the resultant milled rice which might be affected by the accelerated aging of paddy.

Another method of accelerated aging of paddy was conducted by Soponronnarit *et al*. (2008). The method enhanced aging by drying paddy (by fluidized bed drying process) of different grain moisture contents (27.7 and 33.2%, dry basis) with high temperature air (130 and 150°C) and tempering time (0, 30, 60, 90 and 120 min). They reported that aging process in rice was accelerated when KDML 105 freshly harvested paddy was dried with higher temperature and longer tempering time. They found decreases in solid loss and whiteness; increases in water uptake, elongation ratio of cooked rice and volume expansion; and change of pasting property in a similar pattern that could be found in naturally-stored rice, though head rice yield was reported to decrease. Jaisut *et al*. (2008) found similar pasting property change after brown rice cv. KDML 105 had been dried by high temperature fluidized bed drying method. They also reported that the drying process could change thermal properties of the rice samples in which thermal transition of gelatinization such as onset temperature (T_o), peak temperature (T_P), and conclusion temperature (T_C) shifted to higher temperature and enthalpy of gelatinization (ΔH) decreased in the KDML 105 brown rice with increasing drying temperatures (130 to 150^{o}C), moisture content (28.2 and 33.3% dry basis) and tempering time (30, 60 and 120 min). Heat-moisture treatment is another application employed to modify physico-chemical properties that are related to quality factors of cereals products. The heat-moisture treatment was reported to accelerate process of aging in rice, other cereals, and also their products, for examples, maize, sorghum and sorghum meal (McDonough *et al*., 2004), rice starch (Anderson *et al*., 2006), and potato starch (Pukkahuta *et al*., 2007). McDonough *et al*. (2004) reported that accelerated aging by heat-moisture treatment (heating at 50°C in sealed container for 5, 10 and 15 days) affected physical and chemical properties of maize, sorghum and sorghum meal in which the aging treatments significantly decreased pasting viscosity, molecular solubility at 85°C and molecular weight of solubilized starch. In parboiled rice, firmer (or harder) texture was reported to relate with level of crystalline amylose–lipid complexes formed during parboiling and the complexes were stable in cooking process (Biliaderis et al., 1993; Ong and Blanshard, 1995; Priestley, 1977). The amylose–lipid complexes were also found after rice was dried by high temperature employing fluidized bed drying process (Jaisut *et al*., 2008) and this process was used in accelerated aging of freshly harvested paddy (Soponronnarit *et al*., 2008).