# Chapter 5

# General discussion

Rice is the staple food of over half the world's population. In domestic and international rice markets, rice quality is an issue of concern, as consumers are increasingly quality conscious. This study explored the quality characteristics that rice buyers use as criteria for determining the price they pay for farmers' rice. The aroma is the primary characteristic determining premium prices for Thai Jasmine rice. Head rice yield, on the other hand, is an important price determinant for non-aromatic as well as aromatic rice. This report has shown how N fertilization can improve head rice yield by increasing N concentration and storage protein accumulation and distribution in rice grain, so protecting the rice grain against breakage during milling.

## 5.1 Rice quality characteristics that determine price

In Thailand, the world leading exporter of high quality rice, the rice market is highly stratified. Based on quality of rice after harvesting, farmers are paid varying prices, set by buyers. The milling quality of rice is reported to vary with variety, crop management during planting, post-harvest management and ecological conditions (Henderson, 1954; Jongkaewwattana, 1990; Nangju and De Datta, 1970; Yoshida, 1981). In Chapter 2, results had showed how price differentials are determined by rice quality characteristics. Rice price determination by rice buyers is based on several quality characteristics, including grain moisture content, head rice yield, aroma, translucency and vitreousness. The rough rice grain moisture content which is acceptable by rice buyers is not more than 14% wb. In Thailand, an important characteristic of high quality rice is its long, slender grain. Rough rice is therefore evaluated for purity of the particular variety by the grain shape and size and husk colour. Rough rice is dehulled, resulting in brown rice. For non-glutinous rice, brown rice is evaluated for translucency, vitreousness and percentage of contamination with the opaque grains of glutinous rice. For aromatic rice, the aroma is evaluated by sniffing. The ability to do so is very important in buyers of the Thai Hom Mali or Thai Jasmine rice. For glutinous rice, percentage contamination with the translucent non-glutinous grain is also evaluated. Then, brown rice is polished to get milled rice, and head rice recovery is normally them determined.

The present study has found that price was paid to farmers for rough rice of the same variety, KDML105, differed greatly due to aroma levels in rice from central and northern Thailand. Rice grown near Chiang Mai was more fragrant than from Nakhonsawan. These data agreed with Yoshihashi *et al.* (2004), who found the level of 2-acetyl-1-pyrroline (2AP), the main fragrant compound of aromatic rice, in KDML105 varied greatly across geographical regions. The best known Thai Jasmine rice is produced in Northeastern Thailand region, especially at Tungkularonghai. The KDML105 from Tungkularonghai has been found to have higher 2AP (500 μg $kg^{-1}$) than KDML105 grown in northern (300 μg $kg^{-1}$) and central parts of Thailand (100 μg $kg^{-1}$). In the Tungkularonghi area, however, it was also found that the 2AP level in KDML105 samples from an irrigated area was only half of that from rain-fed areas. The authors suggested that in addition to genetic background, aroma may be highly dependent on environmental and cultivation factors which combine to create a unique environment for high aroma. Furthermore, Yashihashi *et al.* (2004) suggested that drought conditions during cultivation may be the main factor affecting aroma in KDML105 as well as other aromatic varieties, such as Basmati, cultivated in India and Pakistan. Therefore, the overall conditions for producing high aroma are outside the management by the farmer. Head rice yield recovery, on the other hand, is the main price determinant for non-aromatic as well as aromatic rice. In Thailand, the export volume of non-aromatic rice, averaged over the past four years, is five times of aromatic Thai Jasmine rice (http://www.oae.go.th/statistic/export). This study further explains how head rice yield recovery after milling may be improved by N fertilizer management.

### 5.2 Nitrogen and rice milling quality

The results of this study clearly showed that N application increased head rice yield since increasing of storage protein abundance in the lateral region of the rice grain. Applying 120 kg N $ha^{-1}$ at flowering increased grain N concentration from 1.3 to 2.0% in all tested varieties and also doubled the density of storage protein in the peripheral region (subaleurone layer) surrounding the rice endosperm. Many earlier studies have reported that N fertilizer increased head rice yield but these investigations did not examine the internal grain structure. For example, Nangju and De Datta (1970) found that application of N fertilizer up to 120 kg N $ha^{-1}$ increased head rice yield of chalky varieties, IR8, IR5 and Sigadis, but applying 60 kg N $ha^{-1}$ increased head rice yield of only Sigadis, the most chalky variety. Furthermore, Seetanum and De Datta (1973) reported that topdressing with N fertilizer (75 kg N $ha^{-1}$) at flowering increased percent head rice of IR8, IR20, RD1 and C4-63. Neither of these studies showed whether the head rice yield was increased by N fertilizer directly through the increased N concentration in the grain nor indirectly through enhanced plant growth and grain filling. In this study results had shown that head rice yield was positively and closely associated with increasing grain N concentration, which in turn increased the abundance of storage protein in the rice endosperm. The increased protein bodies were found to occupy and cement the spaces between starch granules, resulting in increased resistance to breakage during milling. This was evident in CNT1, KLG1 and PTT1. However, the head rice yield of KDML105 was not increased by N fertilization. KDML105 had a high percentage of unbroken rice, more than 90%, at nil N fertilizer. This grain had low grain N concentration. The behavior of KDML105 was similar to IR22 (Nangju and De Datta, 1970; Seetanum and De Datta, 1973), and SML140-10 and MAS-1401 (Fagade and Ojo, 1977). The histological data of KDML105 showed that at low N, this variety still had more storage protein accumulation in the lateral region, the area of the grain where breakage generally occurs during milling, compared with other tested varieties.

**5.3 Nitrogen fertilizer management for rice quality**

The proper management of N fertilizer, both rate and time of application, are potentially useful for optimizing yield or quality (Place *et al.*, 1970). In rice cropping, N application in early crop growth, e.g. at transplanting or tillering, has mostly been used to increase yield by promoting the growth and number of tillers. Late N application, at panicle initiation or flowering, is useful for stimulating number or size of the panicle and also for enhancing grain filling. The data from this study have shown that applying N fertilizer at flowering increased the accumulation of protein in rice grain up to double that in grain from plants not given N. IRRI (1964), Taira

(1970), Seetanum and De Datta (1973) and Patrick and Hoskins (1974) reported that application of N fertilizer up to panicle initiation increased rice protein content and possibly grain yield. Patnaik and Broadbent (1967) top-dressed rice with labeled ammonium sulfate at different stages of growth and found that recovery of N fertilizer was 51% at the booting stage as compared with 37% recovery when applied at transplanting. Applying N fertilizer at flowering increased the head rice yield in some Thai rice varieties e.g. CNT1 and KLG1. This result is similar with many reported studies (De Datta et al., 1972; Seetanum and De Datta, 1973, Islam *et al.*, 1996) where late N application increased head rice recovery after milling. Thus, the managing of N fertilizer can improve rice quality as well as promote crop yield.

**5.4 Nitrogen concentration and soluble protein**

In rice grain, the soluble protein was classified to glutelin, prolamin, albumin and globulin fractions. Increasing N concentration in rice mostly increased glutelin fraction concentration, which positively correlated with lysine (Juliano *et al.*, 1973; Nishizawa *et al.*, 1977). The different classes of soluble protein may not be synthesized concurrently. For example, Islam *et al.* (1996) reported that $^{15}N$ applied at heading was partitioned largely into the glutelin fraction. This suggests that increasing N concentration may increase protein intake in people for whom rice is their staple food as well as increasing head rice yield. Rice provides 50% of the energy and 35-40% of the protein in the average Asian diet (Juliano and Gonzales, 1989). Nanda and Coffman (1979) suggested that improving milled rice protein by 2% (from 7 to 9%) will double the protein intake in the Asian diet from 10 to 20%. However, nutritional value is not reflected in the international demand for rice quality as protein content does not affect rice price (Andrianilana *et al.* 1987, Unnevehr *et al.* 1985), unlike for wheat. At present, the nutrition quality of rice is mainly the concern of consumers. However, in the future high protein rice may attract premium prices if strong demand from consumers can be maintained.

This study also found that soluble protein was more abundant in the subaleurone layer of rice grain, especially glutelin. The result agrees with Cagampang *et al.* (1966) and Houston *et al.* (1968). The glutelin concentration was positively correlated with percent unbroken rice. This may be due to glutelin preferentially accumulating in the peripheral region of rice grain, which may reduce grain breakage during milling. However, this hypothesis still requires proving in further work.

Using equation 2.1 for KLG1 and CNT1 varieties, current urea price (12,800 baht $ton^{-1}$) and 60 kg N $ha^{-1}$ to improve head rice yield up to 90%, the economic benefit of applying N was modeled. The results show that applying N fertilizer is currently only economic where yield is more than 9 ton $ha^{-1}$. However, the rice yields achieved in Chapter 3 was only ca. 3-4 ton $ha^{-1}$. However, the optimum N fertilizer level for promoting head rice yield still requires further work. An alternative strategy for increasing head rice yield is to incorporate traits for rice storage protein accumulation, such as occurs in KDML105, in future rice breeding programs.

From the previous discussion, increasing grain N concentration may depress grain breakage during milling. Islam *et al.* (1996) reported that top-dressing N at heading was effective in obtaining high protein rice. Foliar application of N is an easy way to increase N concentration in the grain. Spraying urea solution on leaves at the heading stage increased protein content without any loss in total amount of harvest

(Nishizawa *et al.*, 1977). De Datta *et al.* (1972) reported that applying chemicals such as simetryne, tenoran, CP17029 and benxomarc at heading also increased protein content up to 1.8 to 2.3% (De Datta *et al.*, 1972). The question now is whether spraying N fertilizer at flowering may also help to increase head rice yield from milling.

### 5.5 General conclusion

This study concluded that determination of aromatic rough rice price was primarily due to aroma levels. In addition to aroma, head rice yield was the another important quality character that is used by rice buyers to determine the rice price of both aromatic and non-aromatic rice as well as glutinous rice. The head rice yield was closely and positively correlated with storage protein abundance in the lateral region of the rice endosperm. Increase storage protein in this region could be managed properly by applying N fertilizer at flowering. Furthermore, the increase of N concentration led to an increase of soluble protein, especially glutelin fraction. Increasing of soluble protein is significant for improving the dietary intake of protein in consumers who eat rice as their staple food.



### 5.6 Future research

This thesis was aimed to explore quality characteristics that impact on rice price and how increasing grain N concentration can reduce grain breakage during milling. However, further research works are required to be investigated in the follow subjects:

1. There is scant information on the location and timing of synthesis of aroma compounds in aromatic rice. Knowledge on this would facilitate experimentation on agronomic practices to enhance aroma expression. An example of the latter is the need to further explore the potential effect of water stress on aroma compounds.

2. This study found that KDML105 had more storage protein in the lateral region at low N concentration compared with other varieties. How varieties such as KDML105 can accumulate more storage protein in the lateral region of rice endosperm at low N concentration requires more work to explain genotype x environment interactions. It would be useful to study in more detail the allocation of N to the grain during seed fill and source–sink relationships.

3. Grain hardness was not able to be measured in this study. However, hardness needs to be measured to explain the relationship between storage protein abundance in the lateral region and grain resistance to breakage during milling.

4. The data obtained from this study suggest that grain N concentration was able to increase by N fertilization at flowering resulted in reducing grain breakage during milling. Hence, options for applying N should be considered including spraying N at flowering to see whether such treatments can increase grain N concentration and improve head rice yield.

5. This study showed that effect of N concentration on head rice yield differed across a small range of genotypes. Therefore, there is need to evaluate the minimum amount of N fertilizer appropriate for specific varieties which are effective in promoting head rice yield and grain protein quality.