Current status of rice production, distribution, processing and utilization in Korea

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Rice has been a staple food crop of Koreans for more than five millennia as in most of Asian countries. Rice production in Korea has been highly dependent on the small-sized, intensively-managed, and costly system due to its traditional role to the society for food supply. During the past decades, researches on rice in Korea have made a big progress to meet the needs of producers and consumers through varietal improvement and technology developments. Innovative approaches in rice research have also been successfully adopted. However, globalization of food markets via WTO and FTA agreements challenges the future of agricultural sector as well as rice industry of Korea. This paper briefly describe the current status, achievements, constraints, and future outlook in rice industry of Korea.

Introduction

Rice has been the most important crop in Korea not only it provides staple food but also it is a major income source of agricultural households (Table 1). Since about 70 percent of all farms cultivate rice and the maintenance of high self-sufficiency ratio of rice has always been an important policy objective in Korean, rice is often considered a political commodity. In viewpoint of national economy, domestic production of rice confers 0.92% of national GDP of Korea, which is a big share as a single commodity. In addition, we recognize that rice paddy field has played an important role in the preservation of ecosystems and environments through holding significant amount of water during rice season.

On the other hand, rice is the best cereal crop adaptable to Korean peninsula, which exhibits the temperate monsoon climate represented by hot rainy summer and cold dry winter. This may be one of the reasons why rice became the staple food in Korea. At one time, more than half of the rice fields were double-cropped with wheat and barley, but recently rice is single-cropped because of the import of wheat and low income with barley production.

Table 1. Number of farm households producing rice and their income

	Unit	1990	2000	2008
Whole number of farm households (A)	x 1,000	1,767	1,384	1,212
Households producing rice (B)	x 1,000	1,525	1,078	857
B/A	%	86.3	77.9	70.7
Whole agricultural income / household (C)	1,000 Won	9,078	19,514	25,843
Income from rice production / household (D)	1,000 Won	4,380	7,758	7,364
D/C	%	48.2	41.6	28.5

With the long history of rice cultivation in Korea, it has deeply penetrated into our daily lives and consists of a significant part of Korean culture. In terms of Korean tradition, rice is not only a main grain but also the symbol of life. For example, most Korean food has to be served with steamed rice and the steamed rice is considered as the main meal. Also, rice has a special meaning for some ceremonies. Rice and rice cake are used at wedding or funeral in some region. At weddings, it signifies the supplication for fecundity, and rice implies food for ghosts at funerals.

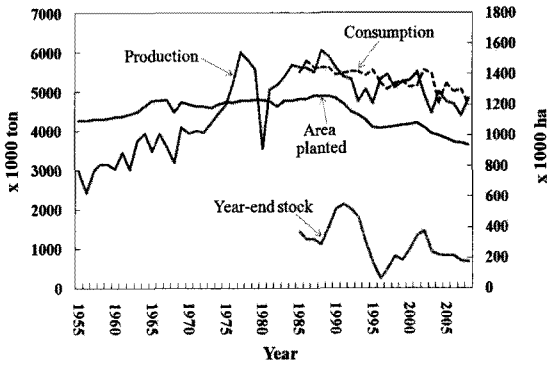

Fig. 1. Area planted, production, consumption, and year-end stock of rice by year in Korea

Rice production and consumption

Korea is the 16th largest country producing rice in the world. Cultivated areas for rice increased gradually from 1970 to 1990 and then sharply declined in the early 1990s due to the Agreement of market globalization of agricultural sector starting with Urguay round. In 2009, rice was planted in 924,000 ha and the area is still decreasing. Rice production was dramatically increased until 1979 due to the yield increase by the development of 'Tongil'-type rice cultivars which had a good yield potential. After 1980, the yield level was almost maintained and the production has been steadily decreased with the reduced planting area. In 2009, the production was 4,918,000 ton and rice yield per hectare reached 5.32 tons in milled rice (Fig. 1).

Varietal improvement of rice in Korea initiated in 1930. A total of 227 rice cultivars are registered to the national variety list of Korea Seed and Variety Service (Table 2). Most of the cultivars were bred at National Institute of Crop Science. After Seed Industry Law was launched on December 31, 1997, a total of 34 cultivars were registered by the other institutes and private sector. During 1970s, 'Tongil'-type rice cultivars were prevalent to meet the national demand of self-sufficiency of staple food. They were derived from three-way cross of indica/japonica//indica and similar to indica in its genetic make-up. However, despite the high yield potential, 'Tongil'-type cultivars were scarcely planted from the late 1980s due to relatively poor eating quality.

Table 2. Number of cultivars of rice registered to the national list in 2010.

Total	Breeder's affiliation					
	National Institute of Crop Science	Provincial/municipal Institute	University	KAERI	Individual	Foreigner
227	193	4	17	10	2	1

Breeding goals have been changed to meet the demand from producers and consumers (Table 3). During the times of food shortage before 1970s, higher yield was the highest priority. Most of the other objectives were concentrated in raising the yield potential through the improvement of plant architecture and in minimizing the yield loss caused by biotic and abiotic stresses. The year of 1976 was commemorable because we achieved the self-sufficiency of rice supply for the first time. Recently, major targets are put to improve

Table 3. Chronological changes of major breeding goals and major events and developments in rice in Korea during the last decades

	Major breeding goals	Major events and developments
1930~1970	• High yield, • Earliness, • Lodging resistance, • Good response to nitrogen fertilizer • Resistance to blast and stripe virus	• Collection of landraces • Pure line selection • Systematic cross breeding • Pedigree and bulk method • Mutation breeding
1971~1980	• High yield and stability • Resistance to diseases and insect pests • Chilling stress tolerance • Grain quality • Earliness	• Creation of Tongil-type cultivars • Development of semi-dwarf HYV • Establishment of RGA methods • Achievement of rice self-sufficiency • International cooperation
1981~1990	• High quality • Yield stability • Multiple resistance • Adaptability to mechanization	• Application of in vitro techniques • Utilization of male sterility • Development of semi-dwarf japonicas
1991~2000	• Super high yield • Palatability and diversified quality • Adaptability to mechanization and direct-seeding • Multiple resistance	• Wide hybridization • Induced mutation
2001~	• Premium eating quality • Diversified quality for processing • Functionality rice • Multiple resistance • Adaptability to direct-seeding	• Marker-assisted selection • Genetically modified rice

Table 4. Changes in rice cultivation technology (NICS)

Year	Planting area (x1,000 ha)	Manual transplant. (x1,000 ha)	Machine-transplanting (x1,000 ha)			Direct seeding (x1,000 ha)			
			Semi-adult seedlings	Infant seedlings	%	Dry paddy	Wet paddy	Total	%
1975	1,218	1,218	0	0	0	0	0	0	0
1981	1,244	1,140	103.7	0	8.3	0	0	0	0
1986	1,236	871	365.0	0	29.5	0	0	0	0
1991	1,208	139	1,051.8	16	88.4	0.3	0.7	1.0	0
1993	1,136	82	651.3	395	92.1	3.6	4.1	7.7	0.6
1995	1,108	0.3	467.2	523	89.4	67.7	49.8	117.5	10.6
1997	1,052	11.9	631.5	298	88.4	57.2	53.4	110.6	10.5
1999	1,066	16.0	800.5	178.8	91.9	26.2	44.5	70.7	6.6
2001	1,056	6.1	803.4	162.9	91.5	43.0	40.6	83.6	7.7
2002	1,039	1.5	810.1	147.3	92.1	20.1	60.0	80.1	7.7
2003	1,002	2.0	780.3	142.1	92.1	13.6	64.0	77.6	7.7
2004	984	1.7	756.9	142.1	91.4	25.1	58.2	83.3	8.5
2005	967	0.9	724.4	168.1	92.3	17.3	56.3	73.6	7.6
2006	945	1.7	893.5		94.6	11.6	38.2	49.8	5.3
2007	950	1.4	904.5		95.2	9.4	34.7	44.1	4.6

the eating quality which assure the market competitiveness of domestic rice. Besides, functionality rices are spotlighted to meet the consumer's demand that is increasingly concerned about healthy food. Breeding methods have been improved and elaborated along with the scientific development. Anther culture techniques have been routinely used from 1980 to shorten the breeding period. Recently, marker-assisted selection technologies are being utilized to identify desirable genotypes with precision in a period of time. Some GM rice, such as insect tolerance, herbicide resistance, etc, are developed. However, GM rice is not allowed yet to grow in the field for production. In 2009, 60 rice cultivars were planted in paddy field for production, of which 10 major cultivars occupied more than 80% of total rice area.

Most of the rice fields in Korea have stable irrigation systems. Rice area per household is 1.09ha in 2009 indicating that rice is produced by small-scaled farmers. Except for the southwestern part of the country, most rice fields are located between mountains with steep slopes. Cultivation technologies have been improved to save the labor and to lower down the production cost. Machine transplanting was started in 1980. Transplanting method of infant seedlings was established to save the cost of raising seedlings. Direct

seeding cultivation initiated in 1991 and reached the largest area in 1995, however the area is not enlarged despite the intrinsic advantage of elimination of raising-seedling stage. The reasons are the relative unstability of seedling emergence, sophisticated weed control method, easy lodging, more irrigation water in direct seeding in dry paddy, and damages by birds and animals. In addition, there is only a few cultivars developed for direct seeding. Recommended amount of fertilizer application is N-P_2O_5-K_2O= 90-45-57 (kg/ha) for transplanting cultivation. Major diseases are blast, sheath blight, bacterial blight, dwarf/stripe virus, and major insect pests are brown planthopper, whitebacked brown plant hopper, rice stem borer, rice leaffolder.

Domestic distribution

Rice distribution channel in Korea is quite complicated. About half of whole rice production are sold to Agricultural Cooperative Association. Government purchases some of rice to control the rice market. The other proportion of rice goes to private sector or directly to consumers. Most of the rice collected from public and private agencies are hulled and milled in Rice Processing Complexes (RPC), and then undergo one or two distribution steps to reach final consumers. This complicated distribution system may cause some problems such as high cost of distribution, difficulty in quality control and management of national stock. Simplified and efficient distribution system is one of the major issues in making agricultural policies.

In Korea, RPCs have been established from 1991 supported by the Government. RPCs are a combined system in which processes after harvesting such as drying, storage, milling, quality control, and marketing are operated in a large scale with an automatized system. However, due to the difficulties in management and financial situation caused by the reduced consumption of rice, they are being restructured including abolition and merger.

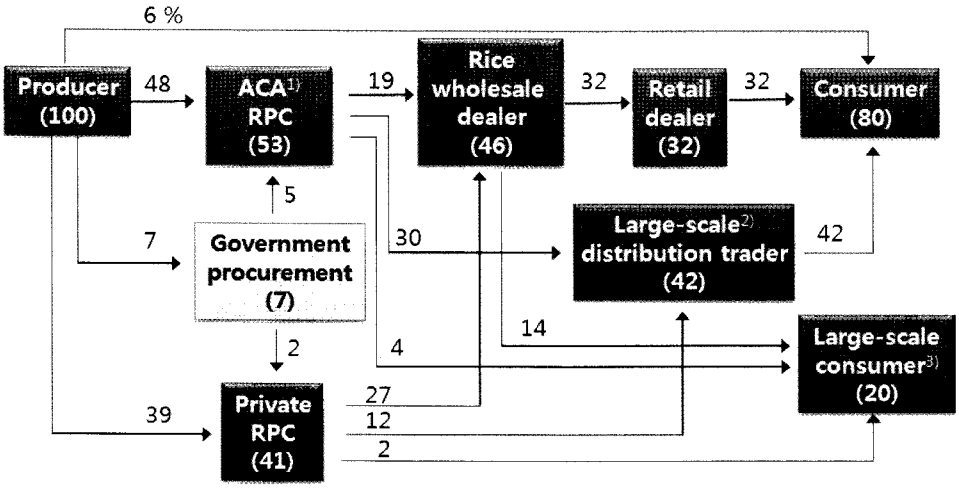

Fig. 2. Distribution structure of rice in Korea (A case study, 2008 - report for Kimje, Dangjin, and Pyungtaek area)

1) ACA: Agricultural cooperative association (농협), RPC: Rice processing complex
2) Department store, Big mart, Hanaro mart
3) Restaurant, Cafeteria, Institutions

Rice consumption pattern and processing industry

Rice consumption per capita per year in Korea have been continuously decreased (Fig. 3). Consumption of cereals shows the same trend. Instead, consumption of animal food is being increased. This indicates that food consumption pattern is being westernized. As a result, it is not strange any more to find heavily overweighted people around us these days.

More than 90% of rice is usually consumed as a boiled rice 'baap'. However, with the increase of single-member family, eating-out frequency and working women, rice consumption is expected to be continuously reduced to a certain extent. Of processed food, rice cake was the top seller, followed by rice wine and cooked rice food Figure 4). However, rice menu in Korea are not diversified as many as in other countries where the rice is consumed as a staple food. FAO have published a recipes book of 300 kinds of rice main dishes in 2004, International Year of Rice.

Recently, with the advent of affluent society, peoples tend to be much interested in healthy diet to maintain or improve health. Some specialty rice varieties have been developed and expanded the market. This trend may be helpful to increase rice consumption by diversified qualities and processed items Table 5).

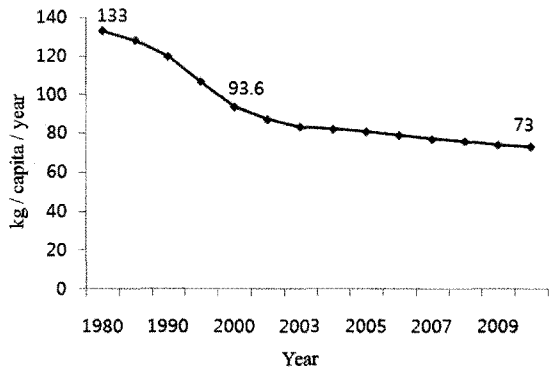

Fig. 3. Yearly changes of rice consumption per capita per year in Korea

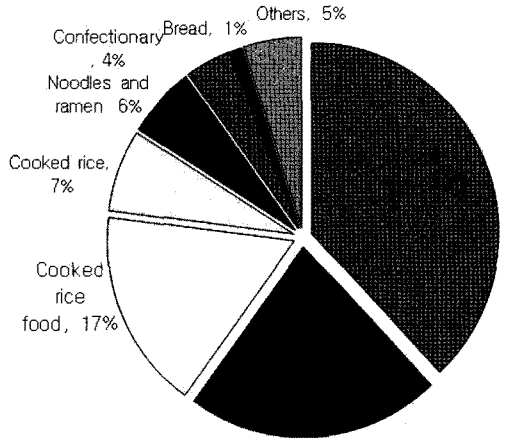

Fig. 4. Several types of processed rice in Korea

Challenges and concerns in Korean rice Industry

As in most of other countries, Korean farmers are suffering from the relatively low income in comparison with city workers (Fig. 5). The income gap between two groups was negligible by early 1990s, however it has been sharply increasing in 2000s. In 2008, the average income per year of farmers was 30,523 thousand Won, while city workers earned 46,736 thousand Won per year on the average. This has discouraged the young generation from staying in rural area and engaging in agricultural industry as well as rice farming. As a consequence, agricultural population are rapidly aging. A census revealed that percent of old-aged people above 65 years old in agricultural population was 33.3% in 2008, whereas that of whole population was 10.3%, and it was projected to be 44.7% in 2020 (Table 6). It is obvious that rice farming will be negatively affected by this trend. Government set up some policies to support the young people to work in agricultural industry, however they seemed not so effective due to the fact that it is not a simple situation but a complicated one in relation to

Table 5. Nutritional function and usability of speciality rice

Specialty rice	Nutritional function	Usability
Large kernel, low amylose, and low protein		Popping and brewing
Scented rice		Enhancing flavor of cooked rice or saccharified and alcoholic beverages
Colored rice	Anti-oxident and anti-cancer activity	Natural pigments for various processed food or cosmetic beauty products
High amylose and high protein		Rice noodle and bread
Fiber-rich and low-digestible starch	Reducing blood glucose, cholresterol, body weight	Low-energy or health-related food products
Semi-glutinous or dull		Popping and brewing, brown rice foods
Floury or sugary	Oligosaccharides	Rice wine, food for patients etc
Giant embryo rice	GABA, tocopherol	Health-related food products, rice oil, brown rice food

(Choi, 2007)

the living standard of young generation in modern society. It appears to be indispensible that reduction of rice area will be continued.

Globalization of agricultural market is another factor frustrating farmers. After the agreement of WTO, since market price of imported rice is significantly low, rice area has been rapidly decreased. Although researches have been focussed to reduce the production cost by technology development as well as varietal improvement, it has not been so successful because rice area of household is not comparable to rice exporting countries and because labor wages, the land price and the price of input are significantly higher than rice exporting counties. Subsequently, market price of rice is going down in spite of relatively higher quality and safety of domestic rice (Table 7). Free Trade Agreement (FTA) between countries are potential threat to rice industry of Korea although rice was an exception in recent FTAs.

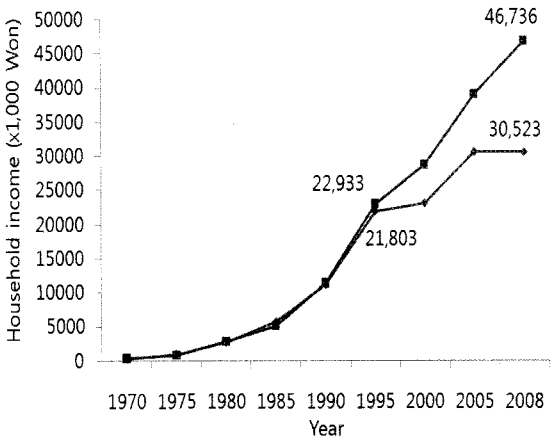

Fig. 5. Comparison of household income between city workers and farmers (MIFAFF)

Table 6. Predicted percentage of old-aged people above 65 years old in agricultural population (KERI, 2010)

	1990	2000	2008	2010	2015	2020
Whole agricultural population (1,000 person)	6,661	4,031	3,187	3,008	2,621	2,283
Above 65 years old (%)	11.5	21.7	33.3	34.8	39.6	44.7

*Percent of above 65 years old people out of whole population in 2008: 10.3%

Table 7. Changes of milled rice price by year (MIFAFF)

		1990	1995	2000	2002	2004	2006	2007
Price at farm	₩/80kg	92,518	117,468	159,816	153,652	158,632	144,174	142,720
Price for government procurement(1st grade)	〃	111,410	132,680	161,270	167,720	167,720	148,075	150,196

Reduction of rice consumption per capita is an obstacle in rice industry of Korea. Rice consumption per capita has been decreased in a rate of 2kg/capita/year (Fig. 3) and this trend will be continued for several more years until the minimum level of consumption is reached, which is presumably estimated to about 60 kg. To make the matter worse, imported rice by minimum market access (MMA) following the Agreement of WTO has stirred up the domestic market bringing about oversupplies in domestic rice markets.

Self-sufficiency rate of other crops but rice is very low, indicating that rice is sustaining our food security although it is only 26.2% (Fig. 6). Due to the high dependency on rice production, food safety might be severly threatened if amount of rice production would not be enough on account of the reduced rice area.

In 2008, rice varieties developed in foreign countries are planted in 16,000 ha (1.7% of whole rice area), and the area has been increasing year by year. This means that domestic rice seed market might be dominated while our concerns are concentrated only on the production and consumption. Recently, we are considering some policies to support seed industry. This policy should not only support vegetable seeds sector but also extend to the seed industry of major food crops. Seed market of food crops makes up more than two thirds of commercial seed market of the world.

Recent achievements in rice research in Korea

Rice researchers in Korea made a big progress in varietal improvement and technology developments. Below are some examples.

- Breeding functionality rice : Several kinds of functionality rice were developed to meet the Increasing concern on healthy food. For instance, Goami 2 and 3 contain the high concentration of dietary fiber and hence will be applicable for a diet food. Giant embryo rice has the high

concentration of ϒ-aminobutric acid (GABA), tocopherol, and oryzanol (Table 5 and 8).

- High-yielding japonica rice varieties : Japonica rice usually yield less than HYVs. Recently in Korea, a high yielding japonica cultivar, Hopumbyeo, was developed by NICS. It's yield potential is 600 kg/10a in milled rice, which is comparable to the yield of Tongil-type cultivars, and it has the top grade of eating quality. It seems that Hopumbyeo will be a new standard for breeding

Annual consumption of food crops per capita (2008)

Total	Rice	Barley	Wheat	maize	Soybean	Potatoes	Others
131.4	75.8	1.1	33.7	5.0	8.0	3.6	4.2

Fig. 6. Self-sufficiency and annual consumption per capita of food crops in Korea (MIFAFF)

Table 8. Functionality rice recently developed in Korea

Cultivar	Functionality components
Goami 2 and 3	High dietary fiber (4~5 times higher)
Hiami	High essential amino acids (30% higher)
Younganbyeo	High lysine (50~60% higher)
Keunnun, Seonong 8	High GABA content (6~8 times higher)
Heugseol	High anthocyanin
Hongjinju	High phenolic acid
Nokwonchal	High dietary fiber (green rice)
Seonong 10	High oligosaccharides

japonica varieties of high yield potential. Supplementation with premium eating quality will be the next target.

- Marker-assisted breeding and GM rice : Some resistant cultivars against diseases and rice brown planthopper were developed through MAS. Multiline varieties against rice blast were bred through MAS blending a few near-isogenic lines which have resistant genes. Resistant cultivars against rice brown planthopper were bred by marker-assisted backcrossing method. A transgenic line which has a strong resistance to rice leaffolder was developed through the introduction of a Bt gene. Various types of golden rice lines which produce β-carotene were created by introduction of different gene sets. GM rice are waiting for the approval to be cultivated in paddy field. Molecular breeding is being a progressive alternative and/or supplementation to the traditional breeding technologies.
- Construction of a geological map of rice eating quality : Eating quality are determined by genotypic and environmental factors. Climate is one of the major environmental factors affecting eating quality. NICS worked out the construction of a geological map of rice eating quality using high quality cultivars. This may help farmers choose appropriate cultivars to grow in their paddy field in order to produce the best quality rice.
- Environment-friendly cultivation technology : High input of fertilizers and chemicals and mechanical deep plowing were considered as a negative role of crop cultivation against environments. To optimize the input, we are practicing precision agriculture in rice cultivation. Recently, recommended application rate of N fertilizer was set to 90 kg/ha. Amount of fertilizer input and application time can be also adjustable by monitoring soil fertility conditions in a large or small scale.

Conclusion

We used to mention food security when food supply was predicted to be unstable, implying that we might be able to purchase food from foreign countries whenever we wanted. However, during the food crisis in around 2008, we experienced that some food-exporting countries banned the export of food cereals and international grain dealers tried to get profit by manipulating grain markets. This suggests that domestic production of staple food is critical to maintain social stability during the food crisis. In this regard, as some economists mention, it might be more reasonable to use the term "food sovereignty" instead of "food security". Recently, global warming and unusual weather worldwide become hot topics. The weather is not stably predictable any more using the meterological database accumulated several decades and so is the agricultural production. All of us should be alert to meet the food unstability anticipated more frequently in the future.

Particularly, international rice market is known to be thin because only 5% of whole rice production are traded. Of them, japonica rice corresponds to 10% of whole trade volume. If japonica rice producing countries have a bad year for rice production, there will be no commercial trade. To assure the stable

production of optimum amount of rice, reasonable policies will be formulated and carried out with the national sympathy. In addition, peoples of non-agricultural sector should be concerned about the future of our agriculture and food production.

With the globalization of agricultural markets, competitiveness of agricultural products is a hot topic. To attain the competitiveness and superiority of domestic agricultural products, research and development for that should be the key solution for the future.

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