A GLOBAL PERSPECTIVE ON THE HIGH FIVE: *AGARICUS, PLEUROTUS, LENTINULA, AURICULARIA* & *FLAMMULINA*

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ABSTRACT

World production and consumption of mushrooms has increased at a rapid rate, especially since the mid 1990s. Not only has production and consumption increased as the world's population has increased, but *per capita* consumption of mushrooms has increased as well. Over a 15-year period (1997 to 2012), *per capita* consumption of mushrooms increased from about 1 kg/year to over 4 kg/year. China is the main producer and consumer of mushrooms. The demand for mushrooms has been phenomenal – production to meet the growing demand is a performance seldom duplicated in agriculture today.

Keywords: world mushroom production, *per capita* consumption

INTRODUCTION

The worldwide mushroom industry has grown at a rapid rate since the late 1990s (Fig.1). World mushroom production has increased more than 25-fold during the last 35 years (from about 1 billion kg in 1978 to about 27 billion kg in 2012). This is a remarkable accomplishment, especially considering the human population has increased 1.7-fold during that same period (from about 4.2 billion in 1978 to about 7 billion in 2012). Thus, *per capita* consumption of mushrooms has increased at a relatively rapid rate and now exceeds 4 kg/person compared to only about 1 kg in 1997. In 2012, nearly all consumption of mushrooms in China, the EU and India was supplied from domestic sources. Alternatively, nearly all mushroom consumption in Russia was supplied from imports while consumption in the United States, Canada, Japan and Australia was supplied mostly by domestic sources but also by substantial amounts of imports (USITC 2010).

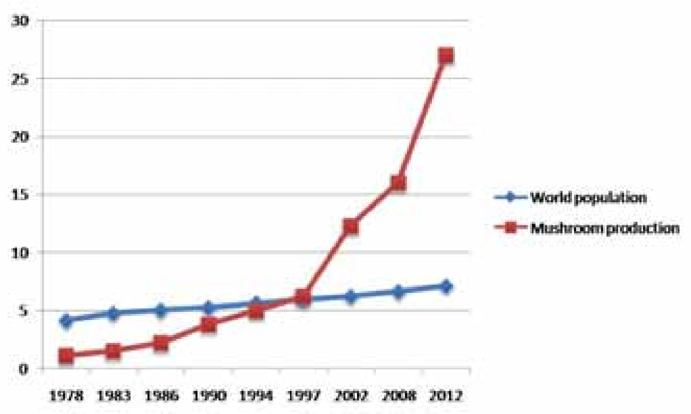

Figure 1. World population (billion) vs. total world mushroom production (billion kg)

Five main genera constitute ca. 85% of the world's mushroom supply (Fig. 2). *Agaricus* (primarily *A. bisporus* with some *A. brasilensis*) is the major genus, contributing about 30% of the world's cultivated mushrooms. *Pleurotus*, a close second, with 5 to 6 cultivated species, constitutes about 27% of the world's output while *Lentinula edodes* (shiitake), contributes ca. 17%. The other two genera, *Auricularia* and *Flammulina* are responsible for 6% and 5% of the volume, respectively.

China is the main producer of edible mushrooms. The Chinese national government has increasingly encouraged Chinese growers to shift their agricultural production out of traditional crops to value-added crops like mushrooms for export (USITC 2010). Estimates of mushroom production in China from 2002 to 2010 vary considerably (Fig. 3). For example, FAOSTAT (2014) estimates mushroom and truffle production in China in 2002 at 2.8 million t while the Chinese Edible Fungi Association (CEFA) estimates production at 9 million t – a 3-fold difference. This conflict is even more pronounced in 2010 where FAOSTAT estimates production at 4.8 million t while CEFA estimates volume at 21.52 million t – a 4.5-fold difference. While these discrepancies remain unexplained, they may be related to the consideration of primarily *A. bisporus*

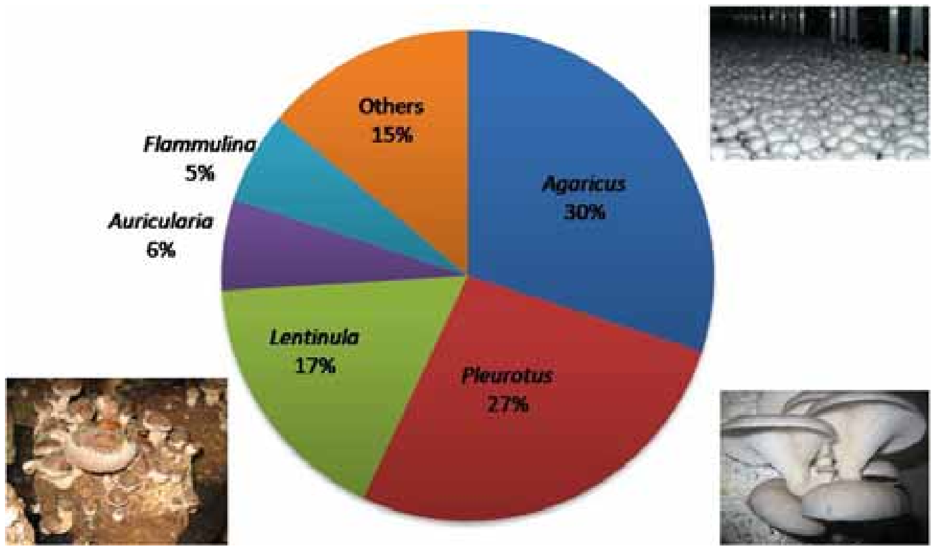

Figure 2. Estimated percentage of world production of edible mushrooms by genus in 2010

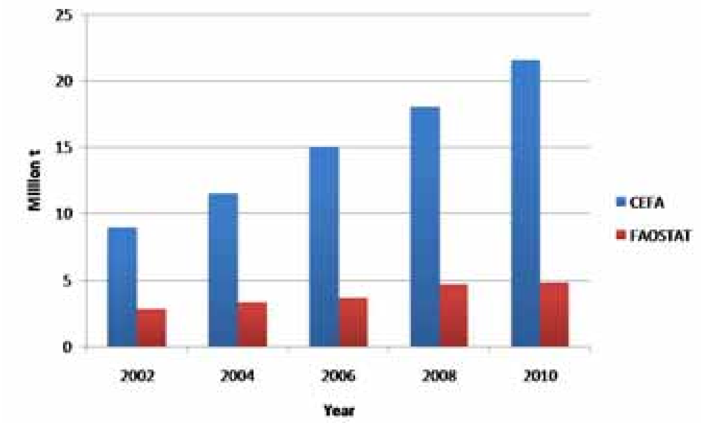

Figure 3. Conflicting estimates of mushroom production in China (2002-2010): Chinese Edible Fungi Association (CEFA, Li 2012) and Food and Agriculture Organization of the United Nations (FAOSTAT, 2014)

in some figures supplied by FAOSTAT and to some degree of over estimation by CEFA. Regardless, China is a very large producer of mushrooms with as many as 30 million growers, processors, suppliers and merchandizers involved in the industry (Chang, 2005).

AGARICUS BISPORUS

Production of *A. bisporus* has continued to increase worldwide especially since the 1950s. Beginning in about 1998, China became the world's leading producer of this species (Chang, 2005). According estimates provided by the CEFA (Li, 2012), China produced over 2.18 million t in 2010, which is about 6 times the volume (350 thousand t) in the United States, the second largest producer of *A. bisporus*.

In the last few years, production of mushrooms in China has gradually moved northward as climatic conditions in the northern provinces are more conducive for mushroom production and raw materials are more readily available compared to southern provinces. Li (2012) expects this trend to continue for the foreseeable future. In the United States, production of *A. bisporus* has increased only about 4.6% over the last 10 years. All of the growth in production of this species has occurred in the brown varieties (portabella and crimini) with the white variety showing a slight decline (-3%) over this period (Royse, 2013).

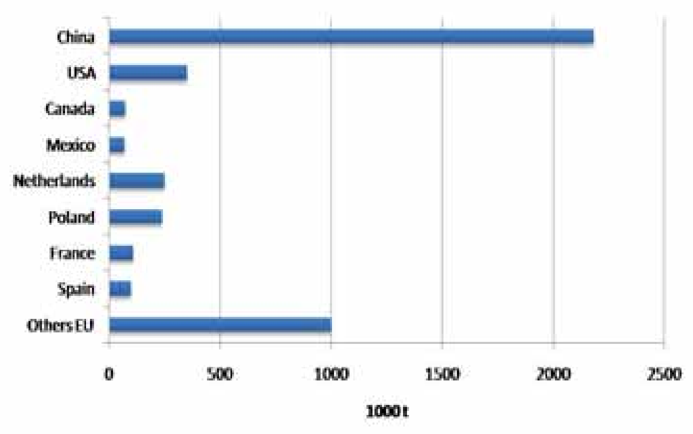

Figure 4. Estimated production of *Agaricus bisporus* in selected countries in 2010

In the Netherlands, the third largest producer of *A. bisporus*, over 90% of production is in the southeastern part of the country, *i.e.*, in the provinces of Limburg, Brabant and Gelderland (Baars, 2012). Approximately 90% of the crop is exported either as canned or frozen (60%) while nearly 30% is exported as fresh mushrooms. The UK purchases about 41% of the fresh supply while Germany, France, Norway, Belgium and Sweden bought most of the remainder of the fresh mushrooms.

Production of *A. bisporus* in Europe continues to move eastward (Royse, 2013). Poland has become a major producer of mushrooms and now nearly equals the output of the Netherlands. Many Dutch-style farms have been constructed recently in Poland – especially in the eastern part of the country (Bieniecka and Dreve, 2012). Nearly 80% of Poland's mushrooms are destined for the fresh market, with Russia and countries in Western Europe importing substantial quantities. Currently, about 90% of the Russian market is supplied by Poland but it is anticipated that the Ukraine will capture a considerable portion of that market in the not-too-distant future (Rozendaal, 2012).

PLEUROTUS SPP.

Oyster mushroom production has increased at a rapid rate worldwide in the last few years (Table 1). From 1997 to 2010, *Pleurotus* spp. production increased from 876 t to 6,288 t (618%). China was responsible for most of the production increase and accounted for over 85% of the world's total output in 2010. Approximately 25% of China's mushroom production in 2010 was from two species of *Pleurotus*: *P. ostreatus* and *P. cornucopiae*. In the last five years or so, however, substantial increases in production of *P. eryngii* and *P. nebrodensis* have occurred. In China, administrative and professional agencies are developing plans to guide farmers in their selection of regions where production and utilization of resources may be optimized for mushroom production. The northeast of China, where the climate is cool and sawdust readily available, is particularly suitable for production of *P. ostreatus*, *P. eryngii* and *P. nebrodensis* (Li, 2012).

In Japan, production of *Pleurotus* spp. increased 198% from 1997 (13,300 t) to 2010 (39,600 t) (Table 1). *Pleurotus eryngii* experienced the largest gains in production, in terms of percentage (+452.8%), increasing from 6,734 t in 2000 to over 37,000 t in 2009 (Yamanaka, 2011). Most *P. eryngii* is cultivated on sawdust of Japanese cedar, or ground corncobs supplemented with bran, and contained in polypropylene bottles.

Other countries in Asia, particularly South Korea, Taiwan, Thailand, Vietnam and India are major producers of mushrooms. Oyster mushroom production in these and other Asian countries collectively have risen nearly 800% from 1997 to 2010 (Table 1).

Table 1. Comparison of production of *Pleurotus* spp. in various countries in 1997 and 2010

Country	**Production (x1,000 t)**				**% increase 1997-2010**
	1997	**%**	**2010**	**%**	
China	760.0	86.8	5,391.0	85.7	609
Japan	13.3	1.5	39.6[a]	0.6	198
Rest of Asia	88.4	10.1	786	12.5	789
North America	1.5	0.2	8.6	0.1	473
Central & South America	0.2	-	1.5	-	650
EU	6.2	0.7	32.0	0.5	416
Rest of Europe	5.8	0.7	28.0	0.5	383
Africa	0.2	-	1.3	-	550
Total	**875.6**	**100**	**6,288**	**99.9**	**618**

Sources: Chang 1999, Li 2012, USDA 2014, Sanchez and Mata 2012, Royse 2013; [a]2009 production (Yamanaka 2011)

LENTINULA EDODES

Until the late 1980s, Japan was the world's main producer of *L. edodes* (shiitake) (Fig. 5). Shiitake was traditionally cultivated in Japan on natural logs of the shii tree – thus the derivation of the name shiitake. Using sawdust-based techniques that reduces crop cycle time and increases production efficiency, however, China became the major producer of shiitake by 1990. From 1995 to 2000, Chinese farmers increased shiitake production from about 0.5 million t to over 2 million t – a huge increase by most standards of measuring change. In 2012, it is estimated that China produced over 4 million t of shiitake and now accounts for more than 90% of total production. Entire communities in China have been lifted from poverty because of the economic opportunity afforded to them by growing shiitake (Chang, 2005).

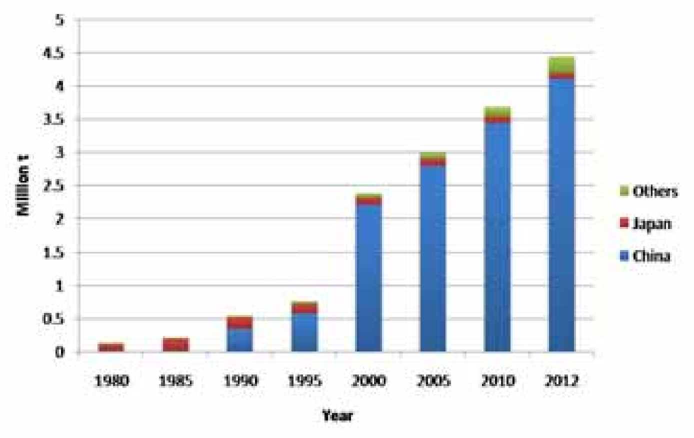

Figure 5. Growth in world shiitake production, 1980-2012 (Chang 2005, Li 2012, USDA 2014, Yamanaka 2011). Author's own estimate for 2012

Production of dried shiitake in Japan has been decreasing steadily since 1984 (Yamanaka, 2011). During the 10-year period 2000-2009, dried *L. edodes* production declined by 37% while fresh *L. edodes* production increased by 11.6%. Production increases for fresh *L. edodes* were due mainly to growers increasing production to fulfill consumer demand left by a decrease in imports in fresh *L. edodes* from China. Total production of *L. edodes* (based on fresh *L. edodes* and dried *L. edodes* converted to fresh weight) was 101,392 t in 2009, which ranked third with 22% of total production of edible mushrooms in Japan.

In the United States, most shiitake production is on nutrient supplemented, sawdust-based substrates (Royse, 2009). Many growers use a 17 to 20-day spawn run then remove the bag for browning of the exterior surface of the "log" while other growers conduct spawn run and browning inside the bag. In general, a longer production period is required when logs are browned inside the bag compared to logs browned outside the bag. In addition, higher rates of nutrient supplement may be used when logs are browned outside the bag resulting in higher yield potential compared to logs browned inside the bag. Over the last 10 years, shiitake production in the United States has remained relatively steady (USDA, 2014).

AURICULARIA SPP.

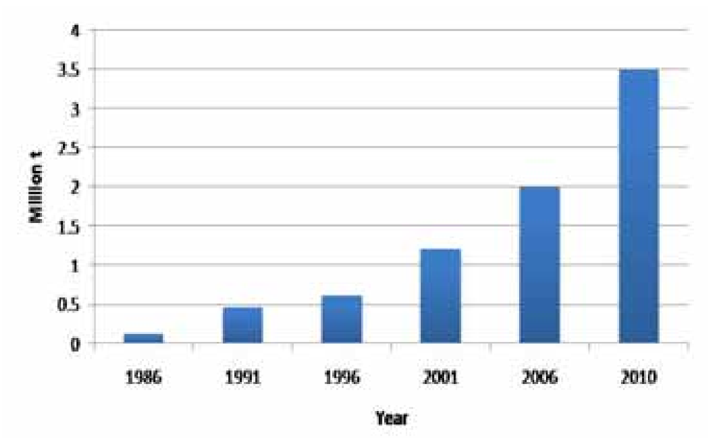

Figure 6. Growth in world production of *Auricularia* spp., 1986-2010 (Royse 1997, Chang 2005, Li 2012)

Now widely cultivated in China, Taiwan, Thailand, Philippines, Indonesia and Malaysia, black fungus or wood ear mushrooms (*Auricularia auricula* and *A. polytricha*) are widely considered to be the earliest cultivated mushrooms (Tang *et al.*, 2010). Production of wood ear accounts for about 6% of the world's total output of mushrooms (Fig. 6). Annual production of *Auricularia* spp. in China alone reached nearly 3.6 million t in 2010 making them the second most widely cultivated mushrooms in that country (Li, 2012). Chinese growers in the two major production regions, i.e., Changbaishan and Shennongjia have been able to domesticate wild-type strains using selections over an extended period (Tang *et al.*, 2010). Some of these selections now have been introduced to new cultivation regions located in the Northern and Southeastern regions of China. Success of the wood ear industry in China may be attributed, in part, to the genetic diversity of cultivars adapted to the prevailing differences in climate, cultivation methods and cultivation seasons (Tang *et al.*, 2010).

Figure 7. Clockwise from top left: 1) *Auricularia auricula* production in bottles (Hawaii, USA), 2) close-up of *A. auricula* emerging from bottles (Hawaii, USA), 3) sun drying *A. auricula* on large mats (China), and 4) sliced *A. auricula* (China)

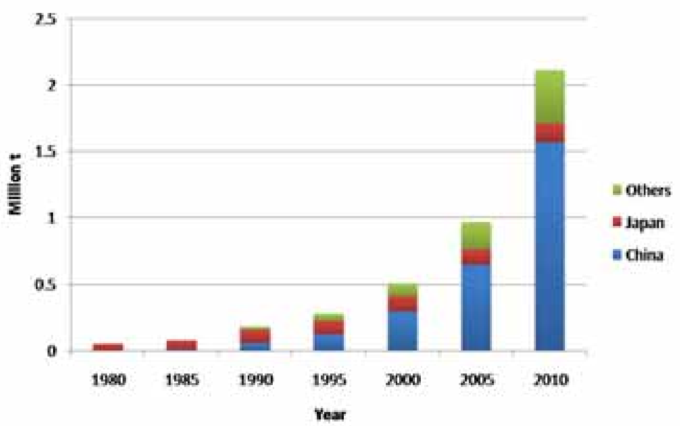

Figure 8. Growth in world production of *Flammulina velutipes*, 1980-2010 (Royse 1997, Chang 2005, Yamanaka 2011, Li 2012)

FLAMMULINA VELUTIPES

From a production standpoint, volume increases of *Flammulina velutipes* (enoki) in Japan and China are similar to those for shiitake. Japan once dominated production of *F. velutipes* – until the mid 1990s when China equaled then surpassed Japan – a similar pattern to shiitake except for the magnitude (Figs. 5 & 8). Production of *F. velutipes* in China has increased from about 0.12 million t in 1995 to about 1.57 million t in 2010 (+1,208%). On the other hand, production in Japan has increased from about 0.11 million t in 1995 to about 0.14 million t (+27%) in 2010.

In the last five years, many new enoki farms have been constructed in China based on bottle technology first developed in Japan. In a description of one recent new farm in China, Dreve (2014) describes the first stage of a large climate controlled plant covering 6.7 hectares of land producing 60 t of enoki per day (21,900 t/year). Thus, this single farm produces an equivalent of about 6% of the total enoki production in Japan. About 80% of the farm's output is destined for the domestic market while the remainder is exported to countries in Southeast Asia and Europe.

OUTLOOK

If history is a guide, the mushroom industry will continue to expand at a relatively rapid rate. Since mushroom production is a relatively labor-intensive industry, mushroom expansion is expected to increase at a faster rate in countries with lower labor costs. In industrialized countries, greater use of mechanized systems and bulk handling of materials for preparation of substrate is expected.

The recent discovery of bioactive components in mushrooms with application to improving human health will provide an additional boost for the consumption of mushrooms. Health-conscious consumers will look to mushrooms to help satisfy their needs for a healthy diet.

Much more research is needed on the bioactive components in mushrooms to determine their biological responses in humans (Feeney *et al.*, 2014). Promising evidence suggests that ergothioneine, vitamin D, β-glucan, and selenium offer positive effects on immune function, intestine function, and weight management. It remains to be determined how often, how much and what species or mixture of species should be consumed to bring about a desired biological response in humans. In the meantime, we can enjoy the culinary characteristics and unique delicacies that mushrooms offer.

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