DOI: 10.36036/MR.29.2.2020.113703
Mushroom Research 29 (2) : 75-111, 2020

Invited Paper

Status and trends in world mushroom production-III World production of different mushroom species in 21st century

Manjit Singh*, Shwet Kamal and VP Sharma

ICAR-Directorate of Mushroom Research, Solan (India) 173213
**Corresponding author*, E-mail: manjitbhandal122@gmail.com

ABSTRACT

Due to almost unimaginable growth in production of shiitake, oyster, wood ear mushroom and *Flammulina* and other new mushroom species, particularly in East Asian countries like Japan, South Korea, Taiwan, China, etc. The contribution of these mushrooms to total world mushroom production has increased tremendously as compared to button mushroom which is no more the number one mushroom in terms of share in global mushroom production. FAOSTAT represents consolidated data of mushroom production but does not cover all the species and countries and species-wise data is not available. Data were hence procured from major mushroom producing countries like Japan, Korea, China, European Union, America, Canada, Australia and others or accessed from the research papers/ databases available. Based on data from different sources, estimated world mushroom production in 2018-19 was 43 million tonne (MT) with *Lentinula edodes* (shiitake) contributing 26%, *Auricularia* spp 21% *Pleurotus ostreatus* (oyster) 16%, *Agaricus bisporus* (button) 11%, *Flammulina velutipes* 7%, *P. eryngii* (king oyster) 5%, *Volvariella volvacea* (paddy straw mushroom) 1% and others 13%. Other important contributors were *Agrocybe aegerita, Pholiota nameko, Tremella fuciformis, Hypsizygus marmoreus*, etc. Production in developed countries is on decline or has reached plateau. Shiitake, *Pleurotus* species, etc which are mostly cultivated in Asian countries, have started making inroads in Europe, America, Canada and Australia where *Agaricus bisporus* is prime contributor. Global production is likely to surpass 50 MT by 2025.

Key words: World mushroom production, *Agaricus*, *Pleurotus*, *Lentinula*, *Auricularia*, *Flammulina*, *Volvariella*

Cultivation of mushrooms like *Auricularia, Flammulina, Lentinula* was attempted hundred years ago in China. 20th century saw the growth of button mushroom along with shiitake, oyster mushroom, *Flammulina*, etc. By end of 20th century the share of button mushroom in total world production was less than 40 per cent. Mushroom production in the present century has undergone many changes. By 2010 button mushroom still had maximum share in global mushroom production (Singh *et al*., 2017). 21st Century, particularly last ten years, have witnessed rapid rise in cultivation of mushrooms other than button. Net result is an exponential growth in world mushroom production. Due to almost unimaginable growth in production of shiitake, oyster, wood ear mushroom and *Flammulina*, particularly in East Asian countries like Japan, South Korea, Taiwan, China, etc, the contribution of these mushrooms to total world mushroom production has increased tremendously as compared to button mushroom which is no more the number one mushroom in terms of share in global mushroom production. FAOSTAT is a robust database

http://epubs.icar.org.in/ejournal/index.php/MR/article/view/113703

of crops including mushrooms and truffles. However, this data is incomplete in many respects and does not give the complete picture (Singh *et al*., 2017). FAOSTAT Code 0449 means "Mushrooms Including inter alia: *Boletus edulis; Agaricus campestris; Morchella* spp. *and Tuber magnatum*" with remarks "Cultivated or spontaneous. Includes truffles." Hence, not clear if it includes wild collection data as well. (http://www.fao.org/es/faodef/fdef07e.htm#7.04) FAOSTAT is not restricted to button mushroom alone nor it covers all the mushrooms. It also does not include many mushroom producing countries. Species-wise data is not available. Values mentioned in the database for many countries represent only 10-20 percent of the actual production. There are variable production reports on world mushroom production. For example FAOSTAT data for 2019 indicates world mushroom production of 11.9 million tonne. Royse (2014), Royse *et al.* (2017) reported production of over 34 million tonne of different mushroom species. Vedder & Vedder (2020) has estimated annual world production of button mushroom alone as more than 2 billion ton (that obviously is a calculation error as this means >250 kg mushroom/ person/year). Data were hence procured from major mushroom producing countries or accessed from the research papers, databases and other sources. Based on data from different sources, species-wise world mushroom production has been estimated.

RESULTS AND DISCUSSION

As per FAOSTAT Total world mushroom production for year 2019 was 11898399 tonne. China, Japan, India, Iran, United States of America, Canada, EU, Russian Federation and Australia accounted for 98% of the the world mushroom production. Major share in production was by Asia (Fig. 1).

Mushroom production in Asia in 2019 as reported by FAOSTAT is 9,854,391 tonne. Within Asia, China, Japan and India accounted for over 97% of the production (Fig.2).

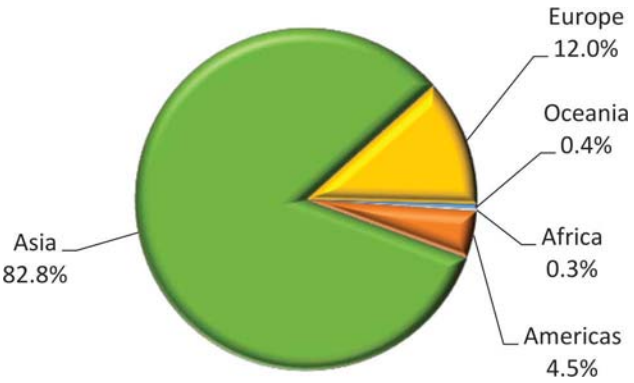

Fig. 1. Continent-wise total world mushroom production in 2019 as per FAOSTAT release in 2021

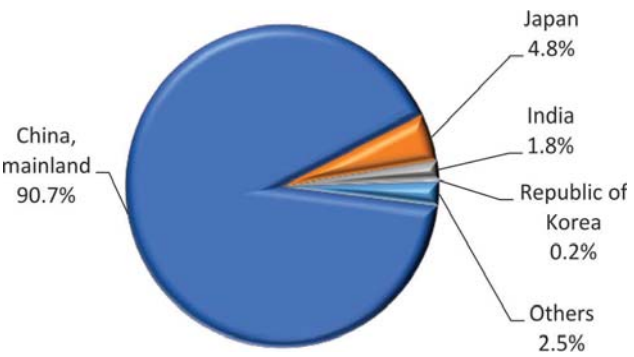

Fig. 2. Mushroom production in Asia in 2019 (FAOSTAT)

Majority of mushroom workers access FAOSTAT that provides figures for total mushroom production. It does helps in understanding the broad picture, though species-wise data is not available. In the present paper species-wise data was collected from different agencies/ sources up to year 2018-19. This includes: China, Japan, South Korea, USA, Canada, Australia, EU countries, India, Bangladesh, Nepal and Others. Based on the species-wise data, the current global mushroom production of different species in different continents is described.

A. ASIA

1. China

In China cultivation was dominated by small scale farmers and they had competitive advantage due to

lower production costs (Li and Hu, 2014). However, now there is shift to quality instead of quantity that means more cultivation under controlled conditions (Li 2012). Despite all mechanisation, mushroom cultivation remains a labour intensive activity. A major share of mushroom production in China was that of wood fungi (Singh *et al*., 2018). There is decline in the availability of wood and saw dust. Even though good amount of work has been done on alternate substrates like cotton hulls and corn cobs, still many growers prefer to use saw dust or logs to get quality mushrooms.

In the beginning, China, like many other countries in Asia like South Korea, Taiwan, India, etc focused on button mushroom using technology from Italy and Netherlands. Primary reason for many Asian countries was to grow mushrooms for export to USA and Europe. Later on many such ventures failed to compete with local technologies or other mushrooms. Even in India, Agro Dutch mushrooms that once claimed to occupy 25% share of canned mushrooms in USA (Timothy, 2010) has failed to survive. This century has seen growth of other mushrooms and number of other species cultivated has been on increase (Singh *et al* 2018). Many hitherto economically important but difficult to cultivate species like *Morchella* spp, *Cordyceps* spp have been brought under cultivation in China in recent years.

Mushroom production in China in 1978 was less than 60 thousand tonne. In last five decades there have been over 650 times increase in production (CEFA) (Fig. 3) and the production in 2019 was 38.6 million ton (Zheng, 2020) (Fig. 4). There has been exponential growth in this century. CAGR of China in last two decades (1997-2018) was 12.37. However, if we split it into two phases then CAGR in first decade (1997-2007) was 17.28 and in second decade (2008-2018) it is 7.57. The growth curve is becoming sigmoid.

There was rapid growth till recently and the rate of growth seems to be slowing down now. In last four years the growth was around 2-3%. The same pattern was seen in developed countries where this slow down and even decrease was observed more than a decade back.

Five genera have been contributing more than 80% of the total mushroom production in China (Table 1). In the present century there seems to be exponential growth in production of shiitake that may stabilise around 11 million tonne (MT). The growth of *Flammulina* is sigmoid and production seem to be stabilizing around 2.6 MT. Growth of *Agaricus bisporus* from 2007 to 2014 was around 2.4 million ton that increased to 3.38 MT in 2015 and has been showing decreasing trend since then and is

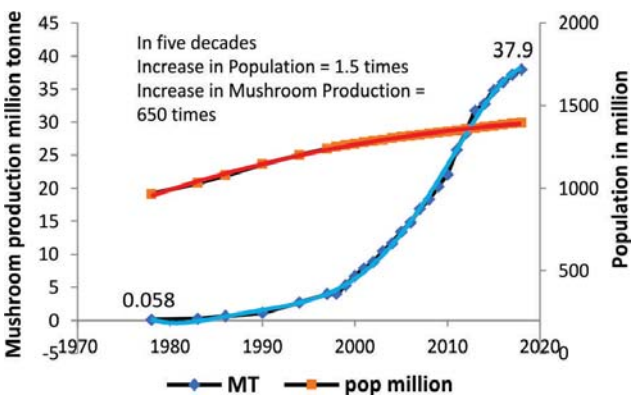

Fig. 3. Growth in mushroom production vs population in China 1978-2018
(Population: https://www.statista.com/statistics/263765/total-population-of-china/)

Fig. 4. Total Mushroom Production in China in 21st Century (based on CEFA - Chinese Edible Fungi Association)

Table 1. Species-wise mushroom production in China (2001-2018) in million kg (CEFA)

Year	*Flammulina velutipes*	*Pleurotus ostreatus*	*Lentinula edodes*	*Agaricus bisporus*	*Auricularia* spp	Others	Total	% contribution
2001	389	2590	2072	743	1124	901	7819	88.5
2003	558	2488	2228	1330	1655	2128	10387	79.5
2005	839	3706	2425	1525	2100	2751	13346	79.4
2007	1178	4146	2885	2441	2554	3616	16820	78.5
2009	1568	4929	3435	2182	3587	4505	20206	77.7
2010	1848	5599	4312	2207	4154	3892	22012	82.3
2011	2493	5633	5018	2462	4896	5215	25717	79.7
2012	2401	5330	6335	2184	6016	6014	28280	78.7
2013	2729	5948	7103	2377	6873	6667	31697	79.0
2014	2513	5458	7690	2301	7317	7422	32700	77.3
2015	2613	5902	7667	3380	8163	7037	34762	79.8
2016	2669	5381	8983	3352	8629	6953	35967	80.7
2017	2479	5464	9865	2895	9205	7212	37120	80.6
2018	2576	6435	10432	2483	8639	7325	37890	80.7

Based on data of Chinese Edible Fungi Association (CEFA)/published works/personal communications

approaching 2.4 MT. The production of *Pleurotus ostreatus* since 2010 seems to be stabilising around 5.9 MT. Growth of *Auricularia* spp. seems to be stabilising around 9 MT. In the genus *Auricularia*, mainly two species are cultivated. Cultivation of *Auricularia* is mainly in China and to some extent in Japan, Korea, Taiwan and other Asian countries only. *A. auricula* in 2018 contributed 78% and *A. polytricha* remaining 22% in production of Auriculariales in China.

In the beginning of this century, *Pleurotus ostreatus* was having maximum contribution to the total production in China. In subsequent years the production of shiitake has increased and the increase is over five times in last two decades. As a result shiitake has moved from second position to first. *Auricularia* spp have moved from third to second and *Pleurotus ostreatus* from first to third position (Fig 5).

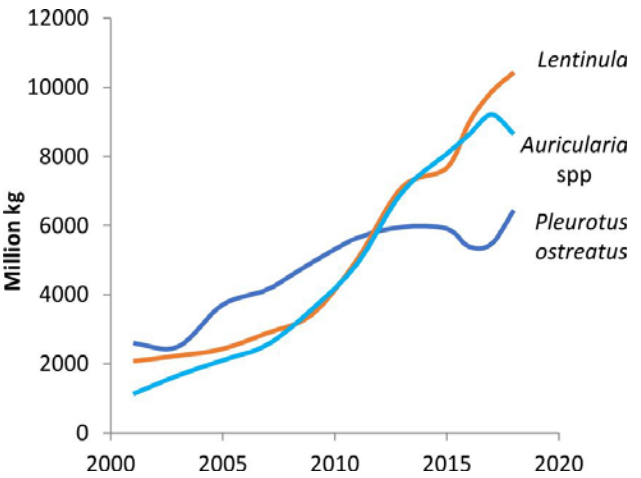

Fig. 5. Growth in production of different species of mushrooms in China from 2001 to 2018

At times production of China appears too much. Comparison of mushroom production of China with Netherlands on basis of production per person showed almost same values. On per sq km basis the production of China was half of that of The Netherlands (Singh *et al*., 2018).

In last few years production of seven species viz., *Lentinula edodes, Auricularia auricula, Pleurotus ostreatus, Flammulina velutipes, Agaricus bisporus, Pleurotus eryngii,* and *Auricularia polytricha* was more than one million tonne in China (Table 2).

Table 2. Species-wise mushroom production of mushrooms having over 1000 million kg production in 2018 (in '000 tonne) in China. (based on data of Chinese Edible Fungi Association (CEFA)/published works/personal commn)

Species	2016	2017	2018
Lentinula edodes	8983	9865	10432
Auricularia auricula	6795	7519	6740
Pleurotus ostreatus	5381	5464	6435
Flammulina velutipes	2669	2479	2576
Agaricus bisporus	3352	2895	2483
Pleurotus eryngii	967	1597	1956
Auricularia polytricha	1834	1686	1898
Others	5984	5615	5369
Total	35967	37120	37890

In last few years the contribution of above seven species towards mushroom production in China was about 84%. There is rapid rise in share of shiitake in total production from 23.5% in 2014 to 27.5% in 2018. *Auricularia auricula* contributed 17.8% and *P. osteratus* 17.0% to the total mushroom production in China.

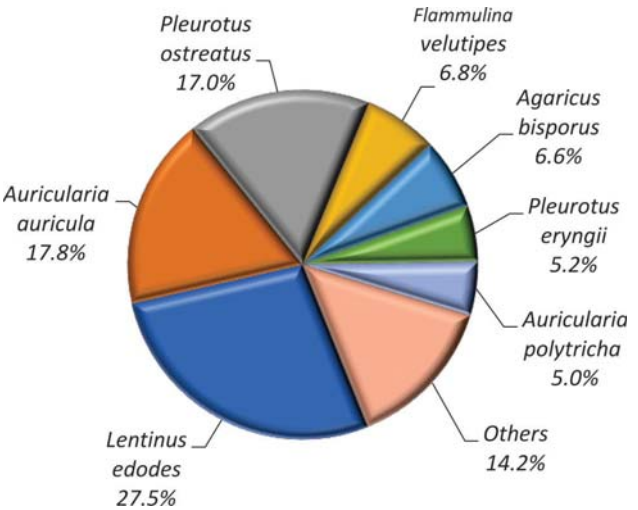

Fig. 6. Relative contribution of seven major species in mushroom production in China in 2018 (source CEFA)

Even though *P. ostreatus* was most popular in the beginning of this century, over the years other *Pleurotus* species are becoming more popular, the most important being *P. eryngii.* In last few years another species *P. geesteranus* is gaining popularity (Fig. 7) possibly because of its shape and flavour. There are number of other species of *Pleurotus* under cultivation. In fact maximum number of species of this genus are reported to be cultivated. There are variable viewpoints about the species concept in this genus and it is apt that we may consider production under two main heads viz., *P.ostreatus* complex and *P. eryngii* complex (Singh & Kapoor 2018).

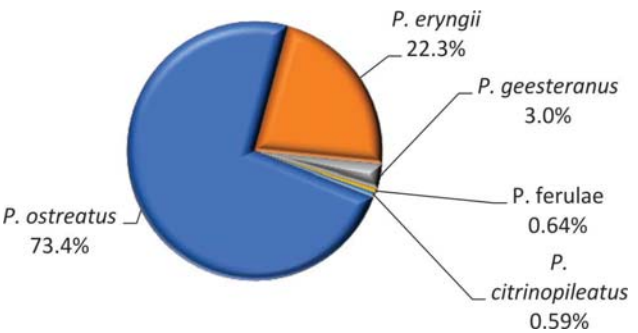

Fig. 7. Relative share of *Pleurotus* species in China in 2018

In many parts of Hungary and Europe the *P. eryngii* (king oyster mushroom) grows on the dead taproot of the tumbleweed which gives the Hungarian name, too (Gyõrfi, 2010). The intensive growing of the king oyster mushroom began in Hungary in 1950 for the first time in the world (Kószó, 1997). At present it is grown in Japan, China, Korea and Italy, etc. In the United States of America its cultivation for sales began in 2000 (Royse *et al.*, 2005; Rodriguez, 2008). Its favourable character is that it can be stored for a long time and its market price is high (Rodriguez, 2005). In China also its cultivation essentially picked up in this century and the production in 2001 was only 21 million kg and it increased to 114 m kg in 2003 (Chang, 2005), 136 m kg in 2005, 202

m kg in 2007, 729 m kg in 2012 and to 1956 million kg in 2018.

Production of *Agrocybe aegerita, Pholiota nameko, Tremella fuciformis, Hypsizygus marmoreus, Pleurotus geesteranus, V.volvacea, Dictyophora indusiata, Ganoderma lucidum, Coprinus comatus, Gastrodia elata* and *Agaricus blazei* in China in 2018 was between 100 to 1000 million kg. There was 2-3 times increase in production of *Dictyophora indusiata* and *Agaricus blazei* from 2016-18 and decline in the production of *Pholiota nameko* during this period (Table 3).

Table 3. Species having production 100-1000 million kg in 2018 (CEFA)

Species	2016	2017	2018
Agrocybe aegerita	713.7	777.6	886.2
Pholiota nameko	1771	653	562.2
Tremella fuciformis	495.8	543.1	525.8
Hypsizygus marmoreus	360.3	391.3	270.3
Pleurotus geesteranus	343.7	324.6	265.9
V.volvacea	213.3	239.2	202.3
Dictyophora indusiata	56.8	199.5	187.8
Ganoderma lucidum	123.7	137.3	167.7
Coprinus comatus	193.1	189.2	148.7
Gastrodia elata	93.3	96.4	105.8
Agaricus blazei	48.5	102.8	100.9

Production of *Cordyceps militaris, Wolfiporia cocos, Boletus* spp, *Hericium erinaceus, Stropharia rugoso-annulata, Pleurotus ferulae, P. citrinopileatus, Lyophyllum decastes, Griflola frondosa* and *Morchella* spp. was between 25-100 million kg (Table 4).

Growth in production of *Cordyceps militaris* from 17310.4 tonne in 2016 to 79738.3 tonne in 2017 to 90559.7 tonne in 2018 and that of *Morchella* from 6025 tonne in 2016 to 10154.3 tonne in 2017 to 24854.7 tonne in 2018 is noteworthy. There was, however, decline in production of *Hericium erinaceus* during this period (Table 4).

Table 4. Some species with production between 25-100 million kg in 2018

Species	2016	2017	2018
Cordyceps militaris	17.3	79.7	90.6
Wolfiporia cocos	81.2	73.8	79.8
Boletus spp	48.3	61.8	64.5
Hericium erinaceus	170.5	88.7	60.8
Stropharia rugoso-annulata	41.6	29.0	57.2
Pleurotus ferulae	93.3	69.1	55.8
P. citrinopileatus	6.9	7.2	51.7
Lyophyllum decastes	3.7	8.6	30.7
Griflola frondosa	24.0	26.4	28.7
Morchella spp	6.0	10.2	24.9

Total mushroom production of China in FAOSTAT is just equal to production of Shiitake as reported by China Edible Fungi Association (CEFA) and is around 22% of total production (Fig. 8).

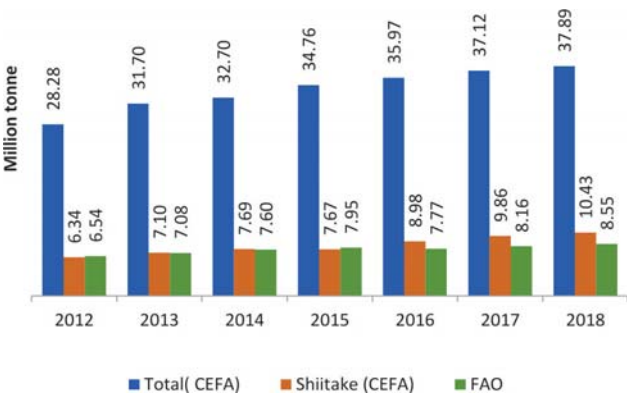

Fig. 8. Mushroom production in China CEFA vs. FAOSTAT

It does not imply that FAOSTAT was representing shiitake production. This comparison is to indicate that FAOSTAT represented only a fraction of production that was just equivalent to one species. In our earlier publication we compared the production with *P.ostreatus* (Singh *et al*., 2018).

2. Japan

Japan is the 2nd highest mushroom producer. Production at the beginning of the century was 384

million kg that increased to 464 million kg in 2010 and in last decade seems to have stabilized around 460 million kg (Fig. 9).

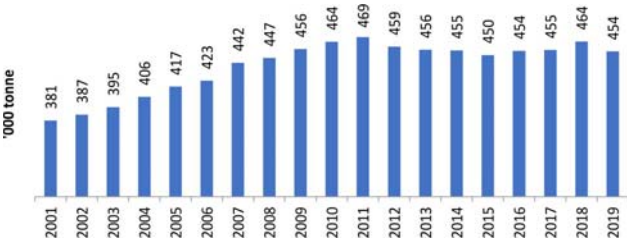

Fig. 9. Mushroom production in Japan in 21st Century (*Based on Ministry of Agriculture, Forestry and Fisheries* (MAFF), Japan)

In the 60s and 70s most of the production was due to shiitake and upto 1988 more than half of the the production was that of shiitake. Up to 1998 shiitake was the number one mushroom in terms of production. Changes in methods of cultivation and genetic improvement of species has lead to increased production of *Flammulina* and *Hypsizygus* and contribution of shiitake came down to 28% in 2000, 22 % in 2010 and at present (2019) the contribution of shiitake to the total mushroom production in Japan is only 19% (Table 5, Fig. 10). Earlier, cultivation on logs was more popular. At present major share of shiitake comes from bag cultivation (Singh *et al.*, 2018).

Table 5. Species-wise mushroom production in Japan (in tonnes)

Ministry of Agriculture, Forestry & Fisheries, Japan (MAFF)

Year	Shiitake	Nameko	Enokitake	Hiratake	Bunashimeji	Maitake	Eringi	Kikurage	Matsutake
	Lentinula edodes	*Pholiota nameko*	*Flammulina velutipes*	*Pleurotus ostreatus*	*Hypsizygus ulnarius*	*Grifola frondosa*	*Pleurotus eryngii*	*Auricularia auricula*	*Tricholoma matsutake*
2001	1,00,879	23,775	1,08,444	6,796	86,550	44,042	10,084	26	78
2002	95,588	24,818	1,10,444	5,800	83,790	46,843	19,472	38	52
2003	94,119	25,068	1,10,185	5,210	84,356	45,805	29,882	56	80
2004	94,823	25,815	1,12,997	4,655	88,066	46,036	33,296	62	149
2005	93,824	24,801	1,14,542	4,074	99,787	45,111	34,342	65	39
2006	93,375	25,615	1,14,630	3,384	1,03,249	45,985	36,435	92	65
2007	92,116	25,818	1,29,770	3,024	1,08,996	43,607	38,265	115	51
2008	97,413	25,945	1,31,107	2,578	1,08,104	43,398	38,214	181	71
2009	1,00,191	26,138	1,38,501	2,424	1,10,741	40,998	37,223	198	24
2010	1,01,693	27,261	1,40,951	2,535	1,10,486	43,446	37,450	302	140
2011	97,125	25,426	1,43,189	2,082	1,18,006	44,453	38,055	643	36
2012	92,414	25,816	1,34,097	1,883	1,22,276	43,251	38,163	819	16
2013	92,437	23,383	1,33,647	2,290	1,17,363	45,453	40,200	765	38
2014	89,093	21,796	1,35,919	2,327	1,15,751	49,541	39,645	894	42
2015	86,284	22,897	1,31,683	3,263	1,16,152	48,852	39,692	1,182	71
2016	88,241	22,935	1,33,297	3,449	1,16,271	48,523	40,475	1,278	69
2017	86,767	22,946	1,35,615	3,828	1,17,712	47,728	39,088	1,710	18
2018	88,196	22,809	1,40,038	4,001	1,17,916	49,670	39,413	2,309	56
2019	87,971	23,285	1,28,974	3,862	1,18,597	51,108	37,635	2,315	14

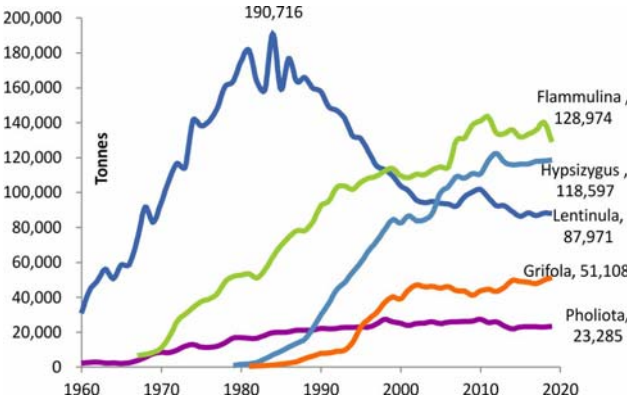

Fig. 10. Species-wise mushroom production of five major species in Japan (1960-2019)

There are only minor fluctuations in the production of *Flammulina, Hypsizygus, Lentinula, Grifola* and *Pholiota* in last decade and the production has stabilised. In 2019 the relative contribution of different species is as shown in Fig. 11.

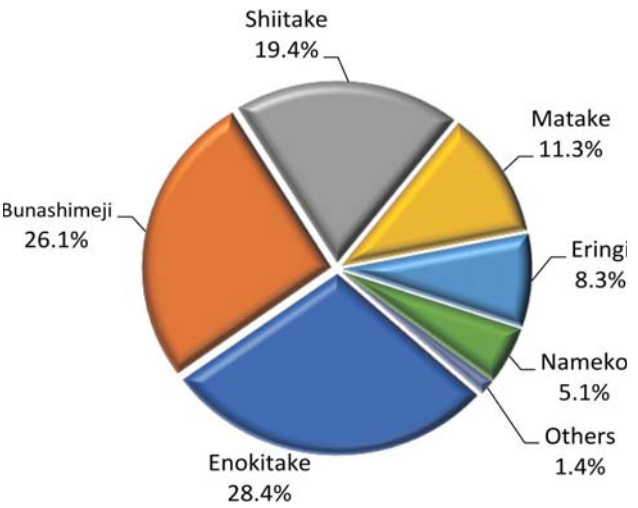

Fig. 11. Relative contribution of different mushroom species in 2019 in Japan

The species-wise production data as available on https://www.maff.go.jp/j/tokei/kouhyou/tokuyo_rinsan/index.html from 1960 onwards is given in table 5.

Similarly. Few decades back, *Pleurotus oesteratus* was the major oyster mushroom species under cultivation with highest production in 1989. It has been almost totally replaced by *Pleurotus eryngii* (Fig. 12).

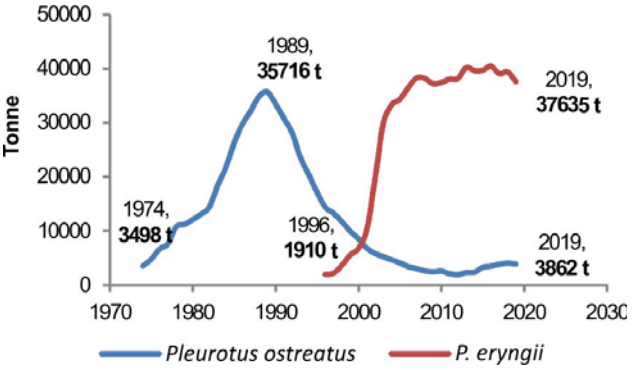

Fig. 12. Production of *Pleurotus ostreatus* and *P. eryngii* in Japan

We highlighted that FAOSTAT data for Japan represented only Fresh Shiitake (dry shiitake not included) [Singh *et al*., 2017]. Thus, FAOSTAT was not representing even the total production of one species and till 2020 FAOSTAT approximately represented only 14% of the total production. Values in FAOSTAT were exactly similar to fresh shiitake production (MAFF) for some years (Fig. 13) or were rounded of for other years. Essentially till 2020 FAOSTAT for Japan was nothing but fresh shiitake production. Upto 2020, FAOStat showed production of mushroom around 65 thousand tonne.

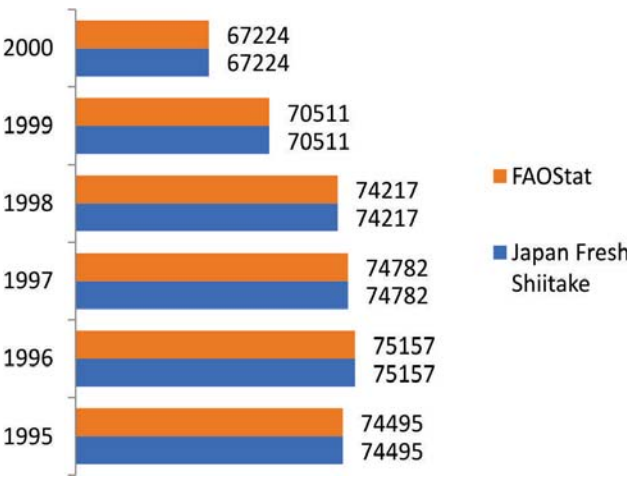

Fig. 13. FAOSTAT vs. data by Ministry of Agriculture, Forestry & Fisheries, Japan (MAFF) [Singh *et al*., 2017]

The information was shared with FAO and the data has been partly corrected in 2021 from 1990 onwards (Fig. 14) and as a result now Japan is the second largest producer as per FAOSTAT.

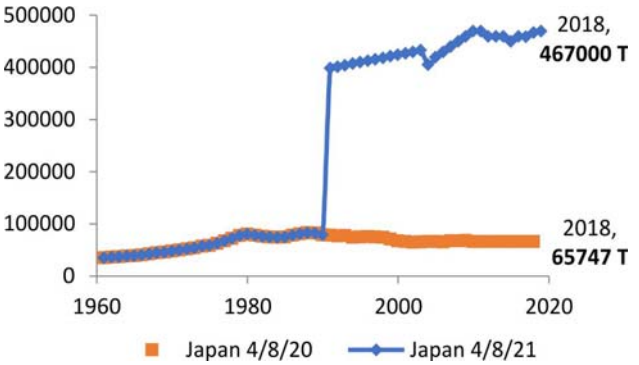

Fig. 14. Mushroom production – Japan upto 2018 as per. FAOSTAT accessed in 2020 and 2021

Before revision Japan and India ranked very low in terms of contribution to total mushroom production. After revision in FAOSTAT Japan and India became 2nd and 6th largest producers in 2019.

3. South Korea

Mushroom production in South Korea can be divided into three phases. Phase I from 1965-1985 where the growth was slow; phase II from 1985-2005 when there was an exponential growth and; Phase III from 2005-2020 where growth has stabilised or has started declining (Table 6, Fig. 15). In Korea, the major cultivated species are *P. ostreatus, P. eryngii, Flammulina velutipes, Lentinula edodes, Agaricus bisporus,* and *Ganoderma lucidum*, which account for 90% of the total production (Yoo *et al*., 2016).

Table 6. Species-wise mushroom production in South Korea (in tonnes)

Year	*P. ostreatus*	*P. eryngii*	*L. edodes*	*F. velutipes*	*A. bisporus*	Others	Total
2001	70,529		34,396	37,955	18,089	3,338	164,307
2002	72,348		37,474	38,072	21,277	10,312	179,483
2003	61,965	18,358	36,203	41,232	19,790	4280	1,81,828
2004	52,211	32,736	38,040	32,796	24,053	15,195	1,95,031
2005	56,866	43,230	38,936	40,161	18,985	3,578	2,01,756
2006	45,782	43,256	37,900	34,400	11,892	6,472	1,79,702
2007	45,967	46,357	39,556	36,864	11,150	6,506	1,86,400
2008	40,071	45,906	39,466	55,231	10,822	6,713	1,98,209
2009	39,159	36,808	43,747	61,057	8,174	9,618	1,98,563
2010	45,191	44,361	39,997	53,187	22,635	10,905	2,16,276
2011	46,598	54,820	36,642	43,098	13,052	9,527	2,03,737
2012	51,991	50,605	30,971	50,841	10,996	13,537	2,08,941
2013	66,039	44,098	26,871	33,416	6,678	11,519	1,88,621
2014	76,389	47,814	25,058	33,259	11,493	14,194	2,08,207
2015	62,467	46,530	30,537	37,554	9,732	11,640	198460
2016	58,784	48,588	28,652	38,092	10,173	7,199	1,91,488
2017	53,532	50,635	29,297	28,535	10,638	7,302	1,79,939
2018	39,675	49,136	26,890	28,532	11,348	8,072	1,63,653
2019	48,327	46,816	25,032	31,818	21,913	4,440	1,78,346

Based on Chang (2006); Yoo et al., 2016; Per. Commn. Won Sik Kong for data from 2016-19. Data of mushroom production by MAFRA and that of shiitake production (dry converted to wet weight) by Ministry of Forests is pooled for total mushroom production by these workers.

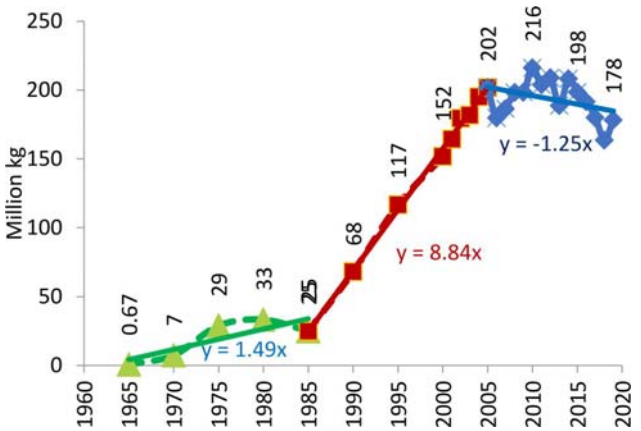

Fig. 15. Total Mushroom Production in South Korea (1965-2019). (Based on Yoo *et al*. 2016 & Per. commn. Won Sik Kong)

At times pooling from different sources may be needed. Data on mushroom production in South Korea is collected by Ministry of Agriculture, Food and Rural Affairs (MAFRA). However, data on shiitake production is collected by Ministry of Forests.

As a result publications based on MAFRA data only lead to the impression that there is no shiitake production. For example Soylu & Kang. (2016) makes no mention of Shiitake production (Fig. 16)

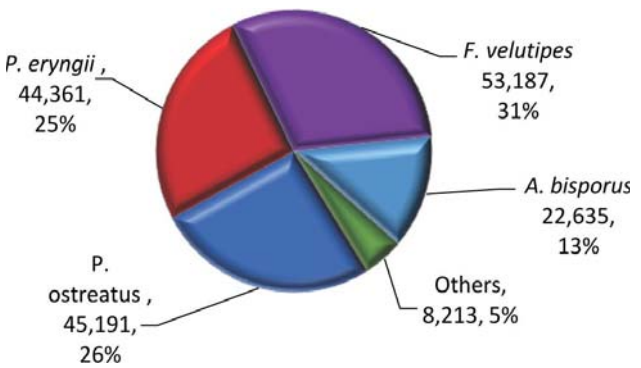

Fig. 16. Mushroom production in South Korea in 2010 (Based on Soylu & Kang, 2016, MAFRA data)

whereas Yoo *et al*. 2016 reported about 18% share of shiitake in total mushroom production in South Korea in 2010 (Fig 17).

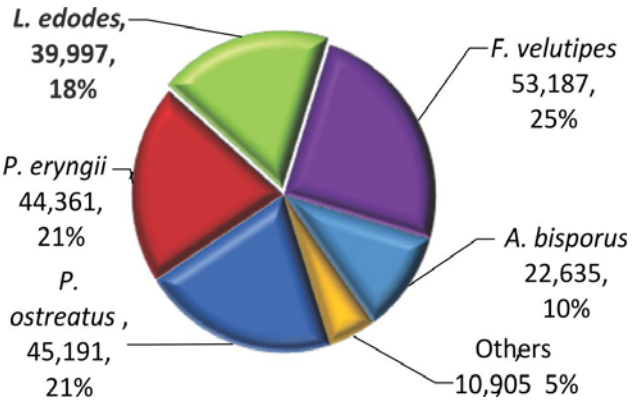

Fig. 17. Mushroom production in South Korea in 2010 (Based on Yoo *et al*, 2016, Pooled data)

Five species accounted for 97.5% of production in S. Korea in 2019. *Pleurotus* spp accounted for 53.4% (*P. ostreatus* 27.1% + *P. eryngii* 26.3%) followed by *Flammulina* (17.8%), Shiitake (14.0%), button 12.3% (Fig. 18).

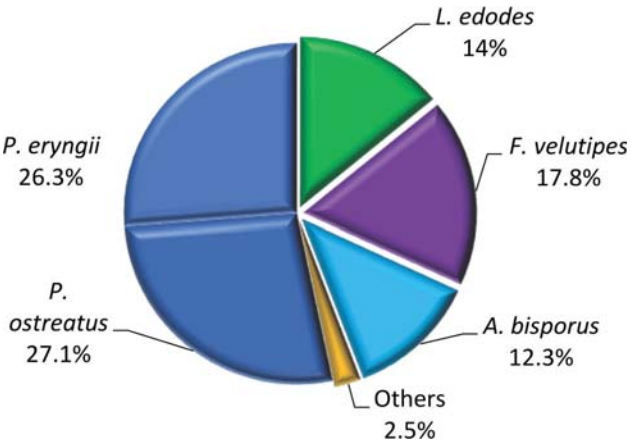

Fig. 18. Mushroom Production in S. Korea 2019

FAOSTAT mushroom production values for South Korea for 2019 are only 12% of the total mushroom production reported above in Table 6 for Republic of Korea. Mushroom production in FAOSTAT is close/identical to the data reported for production of button mushroom as reported by MAFRA (Fig. 19). For example FAOSTAT data in1975, 1980 and 1990 represents production of button only as reported by MAFRA and not all mushrooms. Similar seems to be the scenario for Taiwan (Singh *et al*. 2017).

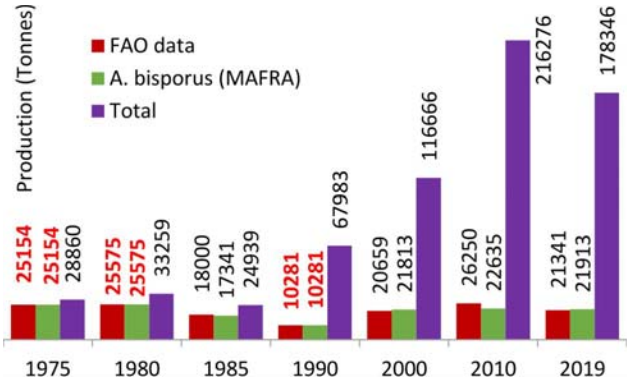

Fig. 19. Mushroom production in South Korea MAFRA vs. FAOSTAT

In the initial years in 70s and 80s, focus was on button mushroom. In the present century, there is major contribution by *Pleurotus* spp and there has been rapid increase in production of *P. eryngii* as has happened in China and Japan. Other species like *Flammulina, Lentinula* and *Agaricus* are showing declining trends (Fig. 20).

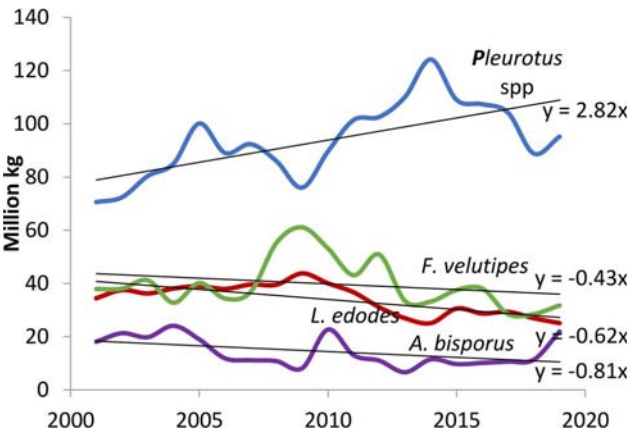

Fig. 20. Trends in production of different mushrooms in South Korea (2001-2019)

By 2012 thirty eight species have been reported to be cultivated (Yoo *et al*., 2016). *Agaricus bisporus* was first recorded as cultivated in 1968, shiitake in 1980, *Flammulina* in 1987. Among *Pleurotus* species, *P. ostreatus* was reported first cultivated in 1974, *P. florida* in 1978, *P. sajor-caju* in 1984, *P. eryngii* in 1997 and *P. ferulae* in 2012 (Yoo *et al*., 2016).

Since mushroom export was initiated in 1960, the export and import of mushrooms have increased in Korea. Technology was developed for liquid spawn production, and automatic cultivation systems led to the reduction of production cost, resulting in the increase in mushroom export. However, some species were imported owing to high production costs for effective cultivation methods (Yoo *et al*., 2016).

Korea began exporting king oyster mushrooms in 2005. Since then volumes that have been exported to Europe has been steadily increasing. Korea currently ships king oyster mushrooms to many countries in Europe, including the Netherlands, France, Germany, Britain, and Spain, via containers (koreittimes.com, 2013).

4. India

In India mushroom production started in 60s and the focus initially was on button mushroom. Production in 2019 was 201 thousand tonne (Fig. 21) Share of button mushroom was 70% (Fig. 22). Contribution of Oyster mushrooms was 17%, that of paddy straw mushroom was 9% and that of milky mushroom (*Calocybe indica*) was 3%. Few other mushrooms like shiitake, *Cordyceps militaris, Ganoderma*, etc account for remaining one percent (Sharma *et al*., 2017).

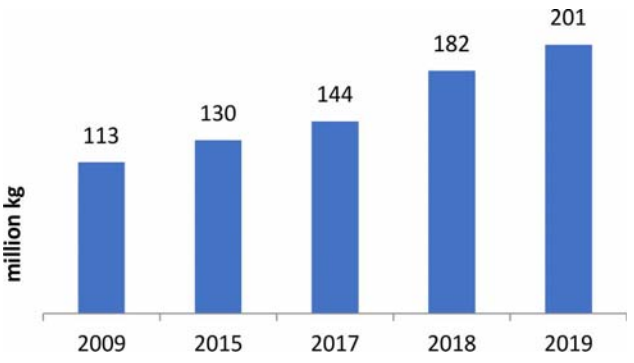

Fig. 21. Mushroom production in India

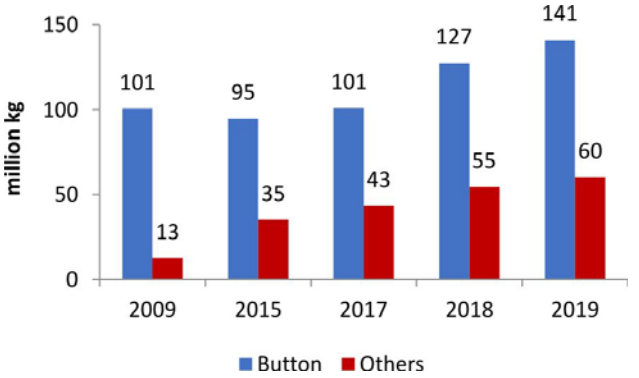

Fig. 22. Contribution of button and other mushrooms in total production in India

FAOSTAT vs Official Data

FAOstat data till 2020 estimated production from India around 40-60 thousand tonne (Fig. 23). The same was communicated to FAO and after correction

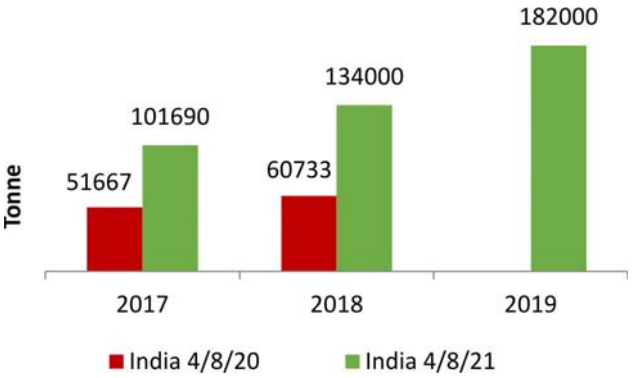

Fig. 23. Mushroom production in India (FAO Stat in 2020 & 2021)

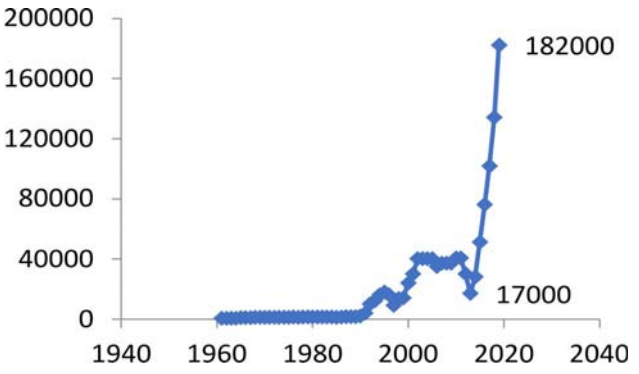

Fig. 24. Mushroom Production in tonne – India FAOSTAT 2021

FAOStat data in 2021 for the year 2019 is 182 tonne. Data has been corrected only for recent years as was the in case of Japan. Hence, sudden rise one may see in FAOStat over years (Fig. 24) is due to non revision of the data for earlier years. As a consequence of revision, in 2019 Japan was second and India was the sixth largest producer (Table 7).

Table 7. Latest top ten in FAOSTAT before and after revision (mushroom production in million kg)

Accessed 4/5/2020 for year 2018		**Accessed 4/5/2021 for year 2019**	
1 China	6675	China	8948
2 USA	416	**Japan**	470
3 Netherlands	300	USA	384
4 Poland	280	Poland	362
5 Spain	166	Netherlands	300
6 Canada	138	**India**	182
7 UK	99	Spain	170
8 France	83	Canada	146
9 Iran	81	Iran	101
10 Germany	73	UK	101

5. Iran

Iran is one of the top ten countries producing mushrooms in the world. White button mushroom, *Agaricus bisporus*, is the most common edible mushroom cultivated in Iran (Ghanbari, 2015). Mushroom production peaked in 2014 (118.8 million kg), a drastic decrease was observed in 2015 (94.2 million kg) and 2016 (63 million kg). During 2014-2017 Iranian Economic was imposed sanctions that affected the trade (Nostratabadi *et al*, 2020). Growth picked up in 2018 and 2019 and the production during this period was 105.2 and 101.4 million kg (FAOStat 2021), though it is still below the 2014 level (Fig. 25). According to Ministry of Agriculture's Greenhouse, Medicinal Plants and Edible Mushroom Affairs (MAGMPEM), more than 160,000 tons of mushrooms are estimated to be produced in Iran during the current Iranian year (March 2018-19).

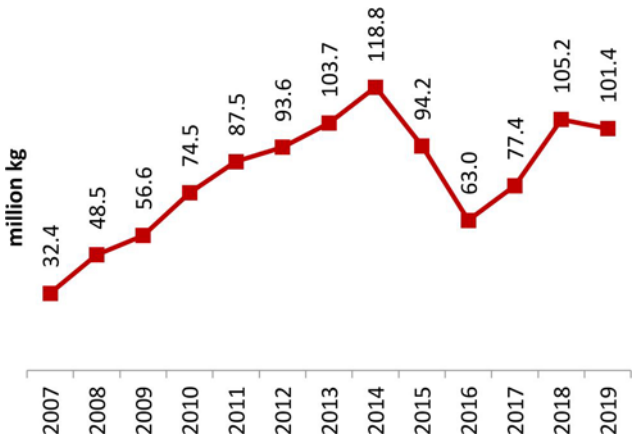

Fig. 25. Mushroom production in Iran (Islamic Republic of) based on FAOStat

Most of the mushrooms in Iran are grown using Dutch technology and are mainly destined for the local market and the average consumption is about 1.2 kg. In Iran, reasonable production levels of up to 24 kilos per square meter are achieved by professional growers (Iran 2021). Units for button production based on Dutch technology are coming up in UAE. Contribution of oyster is less than one percent or so. Of the 62957 tons of edible mushrooms produced in 2016-17, 99.6% was button and 0.4% was oyster. (Nostratabadi *et al.,* 2020). There are attempts to cultivate king oyster in Iran (Jeznabadi *et al*., 2016). Edible mushrooms cultivation activity in Iran is thus mainly in the form of *Agaricus bisporus* and two types of oyster mushrooms. In 2017, there were 1613 edible mushrooms farms throughout Iran, of which 1587 farms were *Agaricus bisporus*, 19 farms were oyster and 7 farms cultivated both types of mushrooms (Nostratabadi *et al.,* 2020). Although the number of oyster mushroom production units is increasing every year and there is rapid increase in production of oyster in terms or percentage, the profitability of *Agaricus bisporus* in Iran is higher (Nostratabadi *et al.,* 2020). Thus the share of oyster is likely to be small.

6. Bangladesh

The climatic conditions and seasonal diversity of Bangladesh is ideal for the cultivation of the oyster mushroom (Amin *et al.*, 2007). The collection of the National Mushroom Development and Extension Centre (Namdec) in Bangladesh includes different strains of oyster mushrooms and new strains like *Pleurotus high king* (PHK), *P. ostreatus* (PO3), and *P. geesteranus* (PG1 and PG3) have been introduced (Mostak *et al.,* 2013). Mushrooms are commercially being cultivated in more than 25 districts of Bangladesh and there are 100 small scale seasonal growers of oyster mushroom growing mushroom in huts in Savar district alone, where Mushroom Culture Centre (made Mushroom Development Institute since 2014) under Bangladesh Agricultural Research Council, Ministry of Agriculture is working since 1980 (Easin *et al*., 2017). About 80% of the oyster is sold fresh where as 20% as dried. Button mushroom, mainly consumed in restaurants, is mostly imported.

In 2018-2019 Bangladesh produced 40,000 metric ton mushroom (Ferdousi *et al.*, 2019) (Fig. 26). Recommended species for cultivation are oyster (*Pleurotus* spp.) and white button mushroom (*Agaricus bisporus*). Mainly, oyster mushroom has been commercially adopted and extensively produced across the country due to its high market demand and suitability under Bangladesh climatic condition. For round the year cultivation of oyster MDI has made production calendar having 12 strains of oyster for different months. In addition to this wood ear, milky mushroom, paddy straw mushroom, *Ganoderma*,

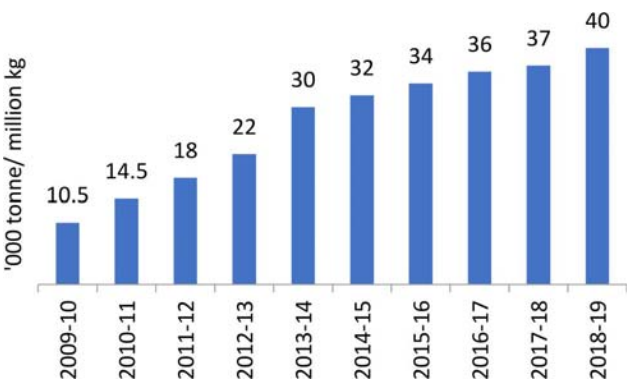

Fig. 26. Mushroom production in Bangladesh based on MDI (Mushroom Development Institute).Annual Report 2018-19, Savar, Dhaka; 2019 (Ferdousi *et al*. 2019)

shiitake and button mushroom are also recommended (Ferdousi *et al.*, 2019). There are several mushroom species and varieties, which have so far been produced or attempted for production in Bangladesh. Mushroom Development Institute has already released 9 varieties of different mushroom species suitable for different seasons of Bangladesh (Ferdousi *et al.*, 2019).

7. Nepal

Mushroom production in Nepal in 2016 was 9300 tonne (Fig. 27). It is estimated that Nepal is producing over 10 thousand tonne.

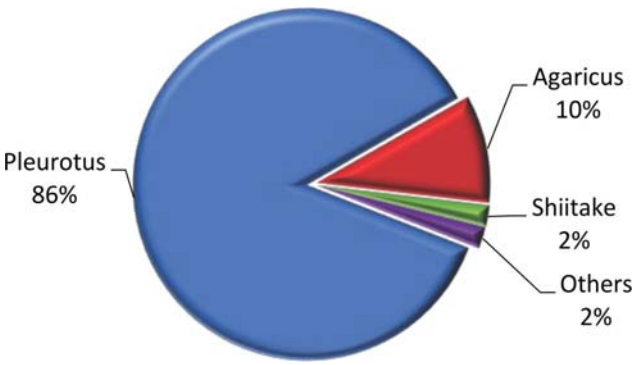

Fig. 27. Mushroom production in Nepal (Based on Jay Kant Raut. 2019.

Major contributor in 2016 was *Pleurotus*. In the coming years production of button mushroom is likely to increase due to setting up of new units.

8. Sri Lanka

The Oyster mushroom, paddy straw (*Volvariella volvacea*) and milky (*Calocybe indica*) mushrooms are some of the high potential cultivable mushrooms in Sri Lanka since they can be grown well under tropical and subtropical condition. *P. ostreatus* is popular in Sri Lanka as a vegetable and as an ingredient in soup. This species is most preferred among the available species because it is very easy to grow under the low tech mushroom farming being practiced in Sri Lanka. In addition, cultivators in the country are also growing *Calocybe indica* and *Volvariella volvacea* (Gamage and Ohga, 2018).

Bangladesh, Nepal, Sri Lanka and many such countries are not appearing in FAOSTAT database.

9. Taiwan

Early success of mushroom industry was based on export market with emphasis on button mushroom (Singh *et al.*, 2017). About 80% of the canned mushrooms sold in the United States in 1963-64 were from Taiwan's central mountains. Annual exports of canned mushrooms peaked in 1978 at US$120 million, before Chinese and South Korean growers ate into Taiwan's share of the global market. Today shiitake, king oyster and *Flammulina* are the major mushrooms. King oyster was introduced in 1991 and its production is more than 20,000 tonne following bottle cultivation technique. *Flammulina*, introduced in 1972, is also mechanized to large extent (Edward-White, 2017).

10. Vietnam

In Vietnam currently, farmers can cultivate 16 kinds of mushrooms with annual mushroom output of 250,000 tons (Vietnam. 2019). Major focus is on paddy straw mushroom, oyster mushroom and button mushroom. Straw mushroom sector has been strongly growing in Vietnam since last decade with more than 64,500 tons/year of production. Vietnamese government issued an agricultural development programme in 2010 in which mushrooms will be the focus to develop as one of five national strategic commodities (Ho, 2017).

11. Others

Mushrooms are reported to be one of the seven high-value crops that are cultivated intensively in Malaysia (http://www.moa.gov.my, 2011). About 94% of the cultivated mushroom are oyster mushroom (Rosmiza, 2016). In Malaysia about 94 % share in production is of *Pleurotus* spp. Indonesia produces

about 37000 MT with major focus on paddy straw mushroom followed by oyster mushroom. Thailand and many other countries are producing various types of mushrooms. Asian countries are still the major producers of mushrooms other than *Agaricus*. Data from this region is important, though not always available or gets misrepresented due to problems in translation, data collection or data communication.

B. AMERICAS

1. United States of America

By end of 19th Century USA was the major player in global production of button mushroom. It was here that white strain was found and popularized, technology for grain spawn and compost pasteurisation was developed. Even today button mushroom contributes 98% of the total mushroom production of USA.

The report by Timothy (2010) provides Mushroom trade summary and includes the structure of the U.S. industry and product trade, including fresh and processed mushroom production, imports, exports, and consumption. for the period CY 2003/04 through CY 2007/08. Present paper mainly covers data on production, export, prices, etc in the 21st century. After continuous rise in last century, the button mushroom production has been fluctuating in the present century around 400 million kg and in last five years, there was continuous decline (Fig. 28, Table 8) whereas there has been continuous increase in production in Canada during these years (Table 10).

Table 8. Species-wise mushroom production (tonne) in USA (2001-2020)

	Agaricus bisporus		*A. bisporus*		Total button	Shiitake	Oyster	Others	Total
Year	Fresh	Processed	White	Brown*					
2000-01	314172	69662	343919	39915	383834	4055	1646	597	390132
2001-02	312964	64020	334083	42901	376984	3640	1830	646	383100
2002-03	316266	63117	329167	50217	379384	3202	1616	584	384785
2003-04	319100	62444	337548	43996	381545	3410	1898	748	387601
2004-05	315845	64303	334549	45599	380148	3908	2326	602	386984
2005-06	319594	58556	324945	53205	378150	3486	2070	539	384244
2006-07	316022	53134	324165	44991	369156	3168	2293	958	375575
2007-08	308300	53371	313932	47739	361671	4388	1929	603	368591
2008-09	308592	56050	314265	50376	364641	4290	2294	619	371844
2009-10	303886	48584	297900	54570	352470	2911	2649	1439	359469
2010-11	325907	57810	321466	62251	383717	3323	3512	1244	391796
2011-12	349913	50090	333743	66260	400004	3628	3189	1398	408220
2012-13	344244	50211	325637	68819	394455	3754	3164	1531	402904
2013-14	348811	51292	330980	69122	400102	4061	3250	744	408157
2014-15	370616	40879	338581	72914	411495	4196	3504	1659	420853
2015-16	373812	43045	341949	74908	416857	4586	4536	1946	427925
2016-17	368145	43079	330033	81190	411224	4902	5029	2209	423363
2017-18	368794	35461	319378	84878	404256	4587	4918	2291	416051
2018-19	339342	29188	285171	83358	368530	3051	3911	1772	377264
2019-20	336019	25205	275629	85594	361224	3181	3863	2030	370298

*(Portabella & crimini). Based on USDA. In FAOSTAT 2019 means July 2018-June 19 data for all the mushrooms.

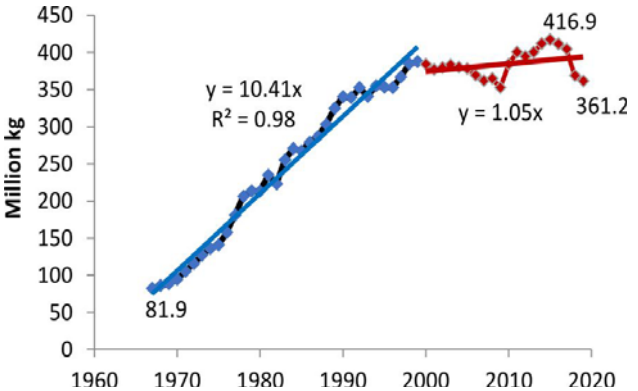

Fig. 28. Total button mushroom production in USA

Over years there is continuous increase in production of brown button (Portabella & crimini) mushroom (Table 8). Only 10.4% of the button varieties produced were brown in 2000/01, that became 15.5% in 2009/10 and 23.7% in 2019/20 (Fig. 29).

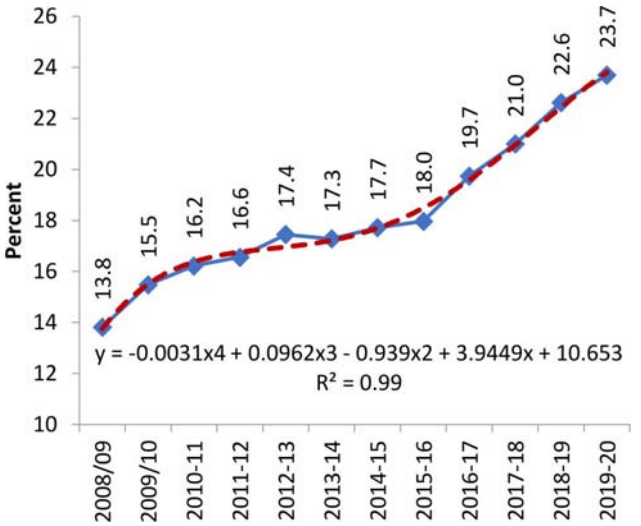

Fig. 29. Percent share of brown varieties in button mushroom production

There is continuous decline in the share of mushrooms for processing (Fig. 30, 31). The demand for processed mushrooms is met through imports.

Average productivity of USA in last decade was 31 kg/m^2. Decline in all places in 2019-20 can be linked to the global conditions during this period.

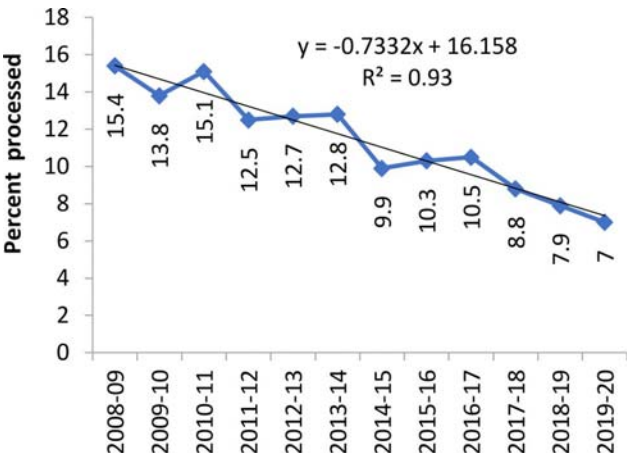

Fig. 30. Percent of mushroom processed in USA

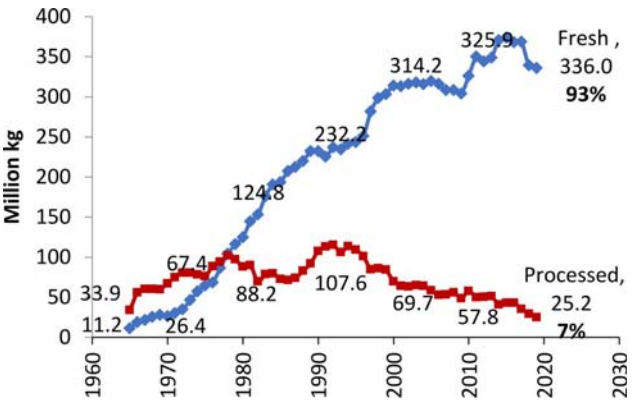

Fig. 31. Mushroom production in USA as determined from sales

Highest productivity was in Pennsylvania in 2018-19, (35.3%) that has declined marginally to 33.5% 2019-20 (Fig. 32).

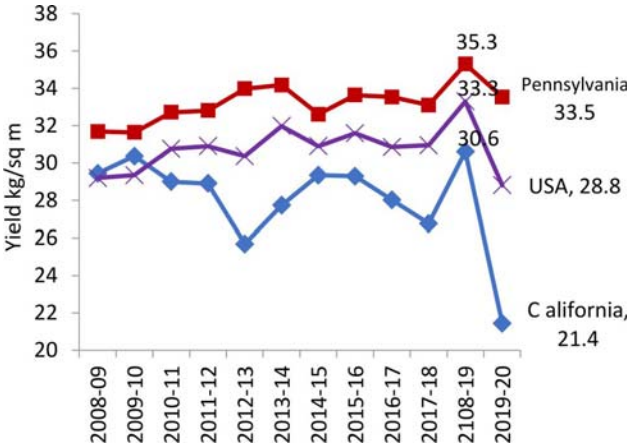

Fig. 32. Productivity of button mushroom

Average mushroom production, share of brown varieties and the mushroom production as determined by sales has been average for last 10 years (Fig. 33).

Fig. 33. Average button mushroom production (2010-11 to 2019-20)

Even though number of farmers growing speciality mushrooms is much higher, still the contribution of these mushrooms to the total production is only 2-3% (Table 8, Fig. 34).

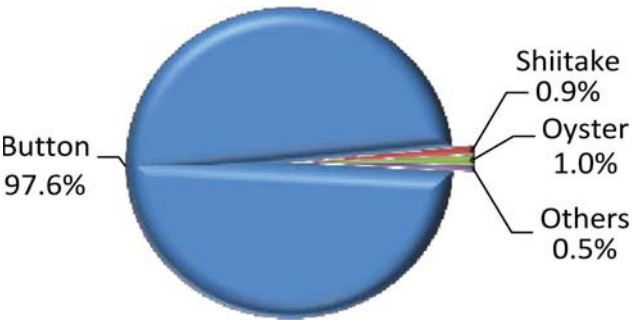

Fig. 34. Share of different species in total mushroom production in USA in 2019-20

Contribution of speciality mushrooms has been negligible in the last century. From 2000 to 2015 the production of shiitake was more or less same and there was slight increase in oyster and others (Fig. 35). In the last five years (2016-2020), however, the production has more than doubled with oyster showing more growth than shiitake.

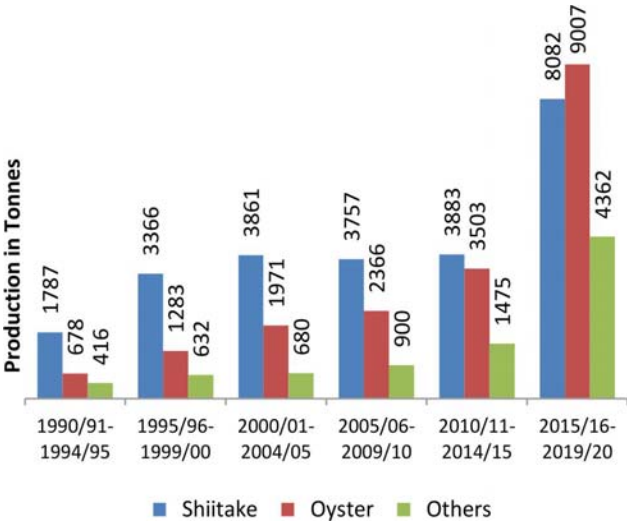

Fig. 35. Five yearly average production of shiitake, oyster and other mushrooms in USA

Region-wise production

Pennsylvania in the East and California in the West accounted for about 80% (66% + 14%) of mushroom production of USA in 2020 and rest of the states account for remaining 20 % (Fig. 36). About 13 % of the mushroom produced in Pennsylvania and other eastern states and Central states is processed whereas only about 2% of the mushroom produced in California and West goes for processing. Kennett

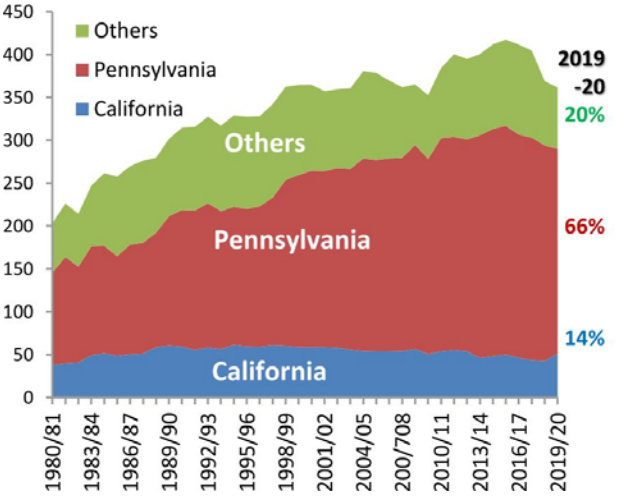

Fig. 36. Mushroom production is localized to two states in USA

Square, Pennsylvania, has become known as the Mushroom Capital of the World, and rightfully so, as 60 percent of the mushrooms consumed in America are grown in Chester and Berks Counties and in recognition of this October 15 was declared National Mushroom Day in 2019 (H.Res. 623 in the house of representatives).

Prices

Prices differ in different regions and have been fairy stable (Fig. 37). Prices for mushrooms as given in Fig 37 are the average prices producers receive at the point of first sale, commonly referred to as the average price as sold. For example, if in a given State, part of the fresh mushrooms are sold F.O.B. packed by growers, part are sold bulk to brokers or repackers, and some are sold retail at roadside stands, the mushroom average price as sold is a weighted average of the average price for each method of sale.

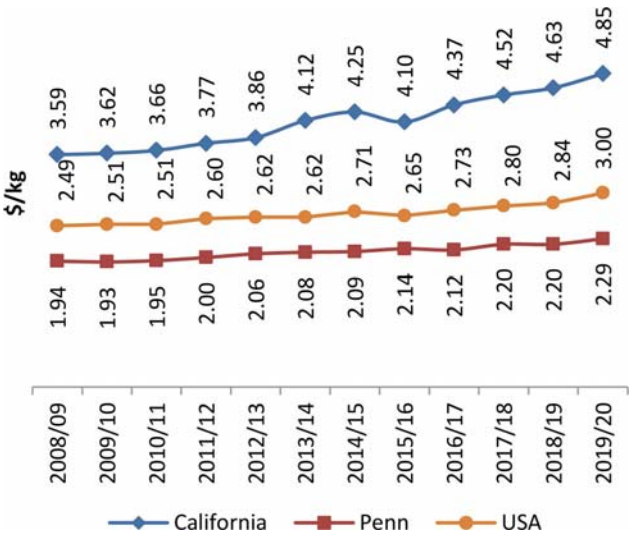

Fig. 37. Mushroom prices in USA

Prices in California are showing continuous increase except a small dip in 2015. In Pennsylvania, prices are almost stagnant with slight increase in last one or two years.

At constant dollar price, prices of fresh mushroom declined more from 1976 to 1982 and decline at constant price of dollar 2009 was relatively slow in this century (Fig. 38).

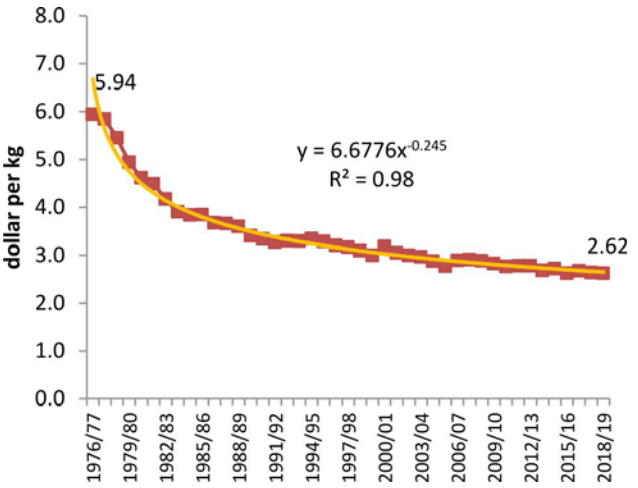

Fig. 38. Constant 2009 Dollar price of fresh mushrooms of all types

In case of processed mushrooms, there was a jump in prices from 1973 to 1976 followed by rapid fall from 1976 to 1982. In rest of the years the decline was gradual. In last five decades or so the prices have become half (Fig 39).

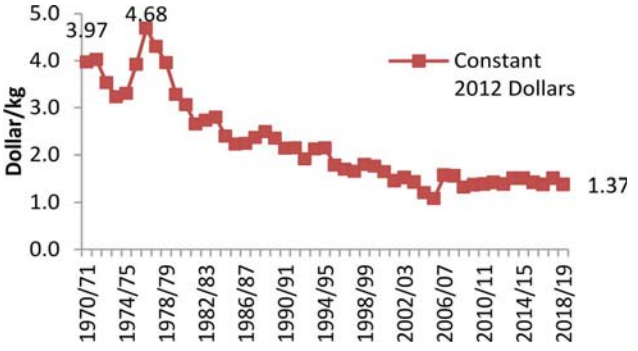

Fig. 39. Price of processed mushrooms (constant 2012 dollars)

Even though the prices of button are fairly stable, there have been fluctuations in the prices of speciality mushrooms (Fig. 40).

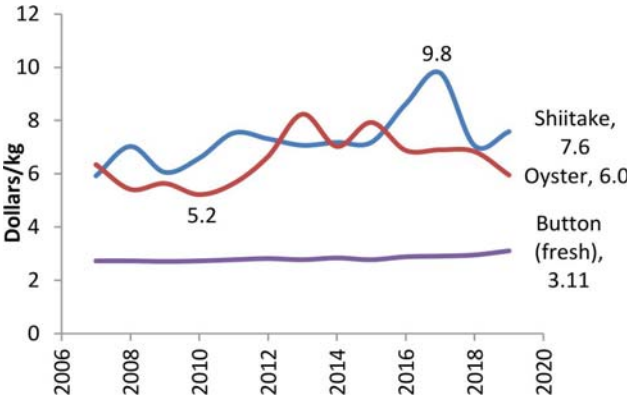

Fig. 40. Average price of fresh mushrooms in USA (2007-08 to 2019-20)

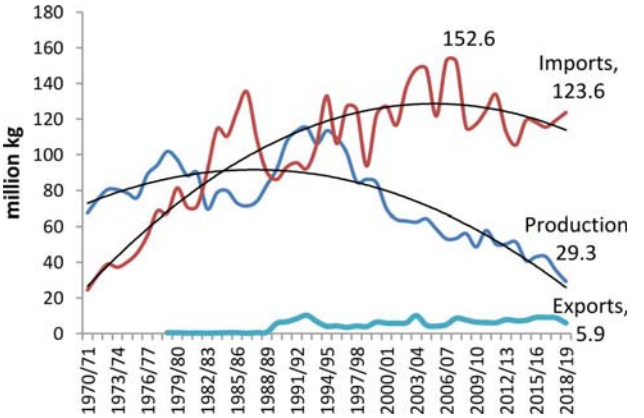

Fig. 42. Production, import and export of processed mushrooms

Import-Export

USA is a net importer of mushrooms (Fig 41). Production of processed mushrooms has been declining over years and its demand is being met by imports (Fig. 42).

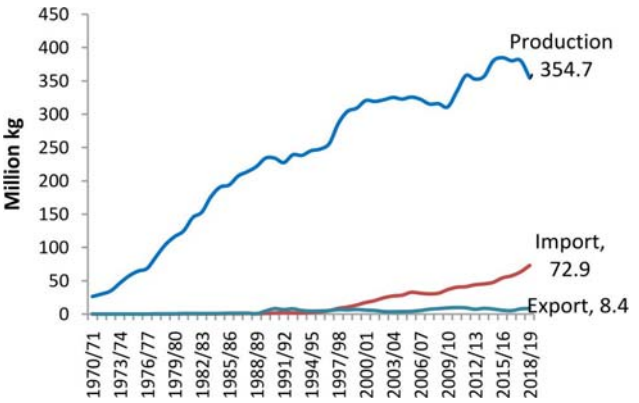

Fig. 41. Production, import and export of fresh mushrooms (button + others) 1971-2019. Fresh production here means fresh button plus all speciality mushroom production. 2019 production data given above is provisional. Actual production for 2019 is 348.08 in corrected data.

Most of the fresh mushroom are imported from Canada and Mexico (Fig. 43) whereas most of the canned mushrooms are being imported from Netherlands (Fig. 44).

Country-wise import in recent years of different mushrooms in different forms is given in table 9. Share of China in imports is gradually declining for dried, fresh button or other mushrooms.

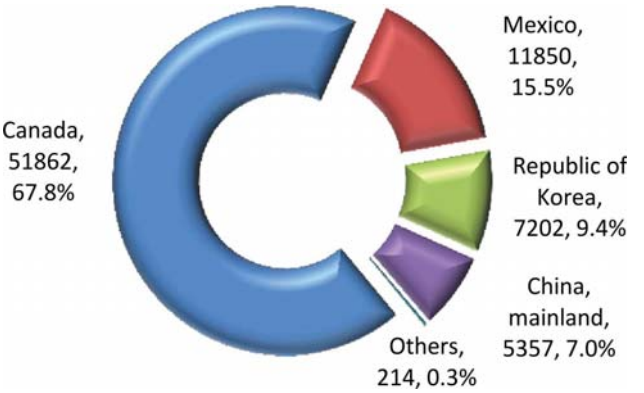

Fig. 43. Import of fresh mushrooms in USA in 2019 (Source: FAOStat)

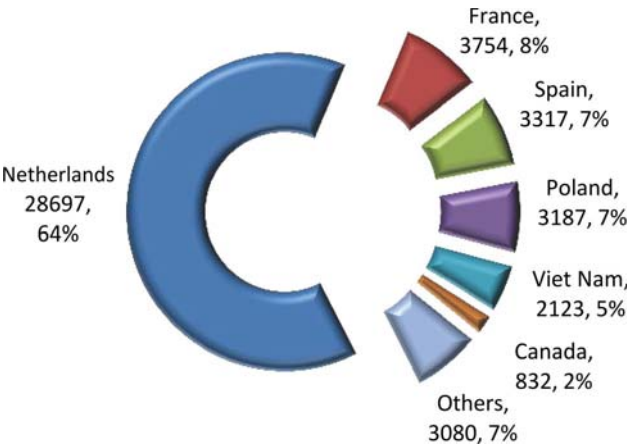

Fig. 44. Import of canned mushrooms by US 2019 (http://www.fao.org/faostat/en/#data/TM)

Table 9. Mushrooms: U.S. import sources by volume (tonne)

	2016/17	2017/18	2018/19	2019/20
Dried mushrooms				
China	2273	2244	2369	2303
France	73	105	91	51
Hong Kong	122	68	59	39
Others	197	192	256	225
Total	2666	2610	2775	2619
Fresh or chilled mushrooms, Agaricus				
Canada	35480	40747	47920	54629
Mexico	8826	8916	11091	12462
China	2461	2736	1739	1340
Ohers	643	780	795	562
Total	47411	53179	61545	68993
Fresh or chilled mushrooms, others				
Korea, South	4924	5453	5883	6262
China	4052	3970	3761	3197
Canada	845	566	1476	749
Ohers	93	114	235	54
Total	9915	10104	11355	10263
Frozen mushrooms				
Total	15979	17497	17787	20137
Preserved mushrooms				
Total	42145	43275	44881	42823

Source: https://data.ers.usda.gov/reports.aspx..

Mushroom Consumption

There has been ten times increase in mushroom consumption in last five decades (Fig. 45) and present consumption is about 1.3 kg/person/year. Even though USA is among the largest producers of button mushroom, still the consumption of this mushroom is below Europe and Australia.

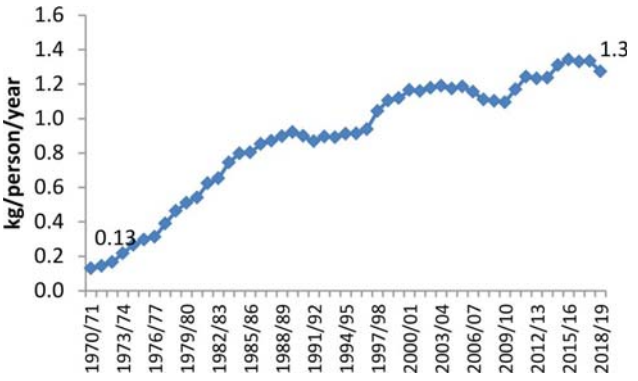

Fig. 45. Per capita availability- fresh mushroom

In 70s about 3/4th consumption was in the form of canned mushrooms. These days their consumption is only 1/4th of the total mushrooms consumed (Fig. 46). Demand for processed mushrooms is mainly met by imports as less than 10 percent of the mushrooms produced in US are processed.

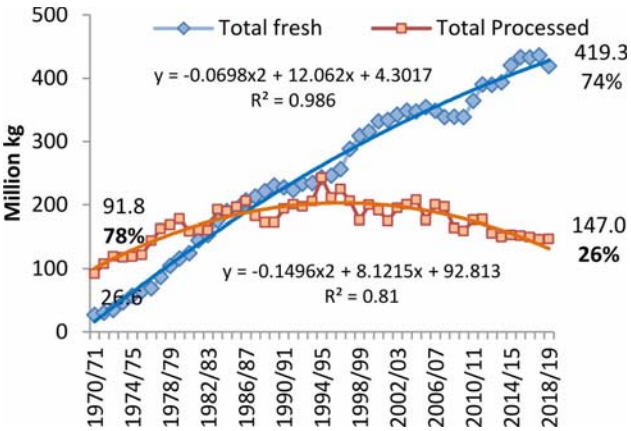

Fig. 46. Total fresh and processed mushroom available for consumption

2. Canada

Mushroom production in the beginning of the 21st century was 86 thousand tonne that has increased to 132.59 thousand tonne in 2019 (Table 10). In the last five years there has been continuous increase. There has been upward growth trend since 70s as can be seen in decadal average (Fig. 47). However, when we look at annual production we can see a sudden jump

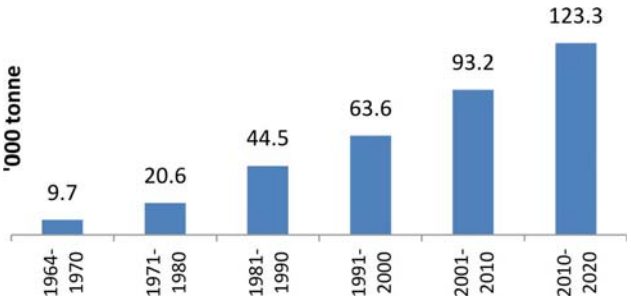

Fig. 47. Decadal average of mushroom production in Canada

in production from 2007 to 2008 (Table 10) and jump in productivity from 2005 to 2006. *Agaricus bisporus* is the principal mushroom species cultivated in Canada, representing at least 95% of the production. Two varieties are cultivated, a hybrid white/ off-white and a brown. The brown variety, depending on the degree of its maturity at harvest, is known in the market as portabella (open with gills exposed) or cremini (closed with no gills exposed). About fifteen to twenty per cent of the total Canadian production is the brown variety.

Table 10. Mushroom production in Canada (tonne) in 21st Century

	Quantity sold fresh	Quantity sold processed	Production (fresh and processed)
2001	77,279	9,078	86,357
2002	64,726	10,349	75,075
2003	77,609	10,329	87,938
2004	75,261	9,421	84,682
2005	73,724	6,348	80,073
2006	77,966	11,313	89,279
2007	73,258	10,032	83,289
2008	1,03,516	12,838	1,16,354
2009	1,03,217	11,243	1,14,459
2010	1,02,798	12,097	1,14,895
2011	1,10,560	11,614	1,22,173
2012	1,13,921	10,905	1,24,826
2013	1,09,923	10,232	1,20,155
2014	1,12,425	9,632	1,22,057
2015	1,11,718	2,965	1,14,683
2016	1,11,729	6,983	1,18,711
2017	1,13,208	7,046	1,20,253
2018	1,17,916	7,649	1,25,565
2019	1,24,533	7,582	1,32,114
2020	1,21,044	11,545	1,32,589

Based on statistical Canada 2021. Speciality mushroom account for about 2-3 % of the production (Simon Beaulieu-Fortin. 2019)

According to Simon Beaulieu-Fortin (2019) the share of exotics was around 2% from 2012-2017, even though there is increase in number of farmers growing exotics from 5% in 1990 to 81% in 2017 (Fig. 48).

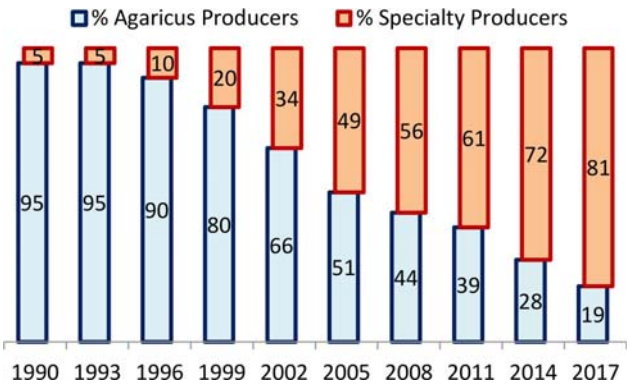

Fig. 48. Percentage of *Agaricus* and speciality mushroom producers (based on Simon Beaulieu-Fortin (2019)

The market share of exotics is small and it is presumed that the share will be around 2-3 % during 2018 and 2019.

In 60s about 40% of the mushrooms were consumed fresh and 60% as processed. In 1973 half of the production was processed, in 1979 25% was processed and in 2015 only 2.6% was processed that increased to 8.7% in 2020. According to Mushroom Growers' Survey, 2020 (Table 32-10-0356-01) the impact of the COVID-19 pandemic was reflected by the shift in sales from fresh to processed mushrooms. The amount of mushrooms processed rose a record 3963 tonne to 11545 tonne in 2020 (+52.3%), with most of the sales occurring at the beginning of the pandemic. Conversely, fresh mushroom sales declined 3489 tonne from 2019 to 121044 tonnes (-2.8%). While cultivated (-1.4%) and harvested (-2.8%) area both decreased in 2020, better yields contributed to higher production. The total value of mushrooms sold rose 5.1% to $619.7 million in 2020, due to higher prices for both fresh and processed mushrooms.

The average production per sq m in Canada in last two decades was 24-25 kg. Productivity from 2001 to 2005 was slightly less and it was more than 24 from 2008 to 2020.

More than 90% mushrooms come from two provinces, viz., Ontario and British Columbia, Ontario accounts for more than half of the production and BC accounts for about 40 percent of the total mushroom production.

In 2019 Ontario accounted for over 50.5% whereas BC accounted for 42.7% of the production (Fig. 49).

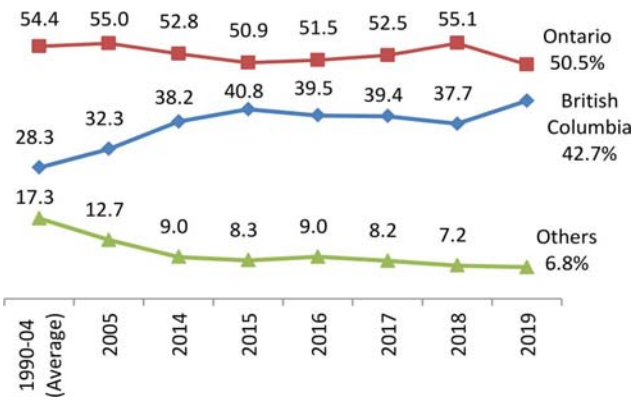

Fig. 49. Region-wise mushroom production in Canada (Statistics Canada 2021)

FAOStat vs CanStat

FAOstat data matches in values with CanStat but not the units. It has been clearly stated in the definition of variables under Mushroom Grower's Survey that the data on crop production variable is in short ton (Statistics Canada, 2020). This short ton data has been reproduced as such in FAOSTAT. Due to non-conversion of units from short ton to metric tonne, yield reported every year by FAOSTAT for Canada is 9.3% more than the actual production (Fig. 50).

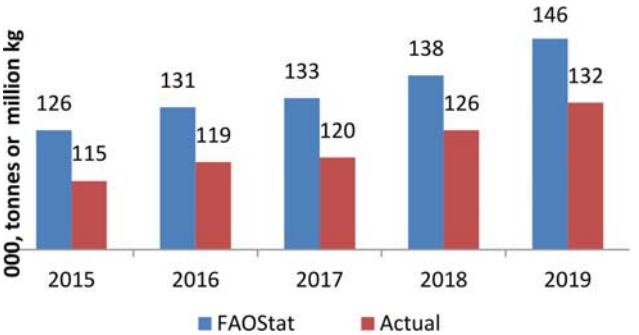

Fig. 50. FAOStat vs. CanStat vs. Actual production in tonnes

Export

Over 1/3rd of the production is exported. In 2017 Canada exported 31.7% of its production that has increased to 43.2% in 2020 (Table 11). Around 99.5% of fresh mushroom export is to USA. Even though Ontario produces more mushrooms than British Columbia, But share of BC in total export is more. In 2020 BC had 2/3rd share in total fresh export (Fig 51).

Table 11. Total Export (tonne) of fresh mushrooms from different provinces

	BC	Ontario	Others	Total	% export
2012	17639	13704	109	31452	25.2
2013	17560	14238	126	31924	26.6
2014	18597	12477	7	31081	25.5
2015	21075	11424	3	32502	28.3
2016	25229	12164	165	37558	31.6
2017	27524	10606	42	38172	31.7
2018	32483	13504	17	46004	36.6
2019	35640	16513	24	52177	39.5
2020	37934	19312	41	57287	43.2

Based on CIMT.2021. https://www5.statcan.gc.ca/cimt-cicm/home-accueil?lang=eng

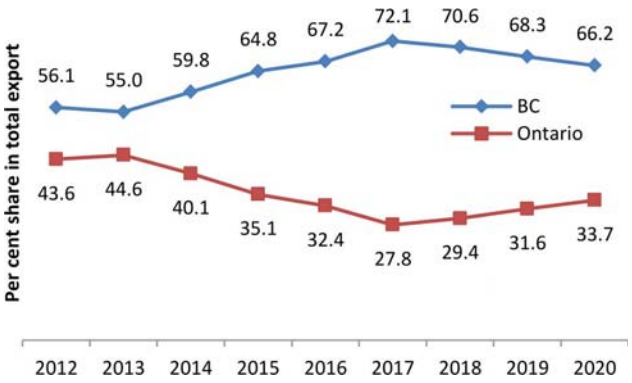

Fig. 51. Percent share of different provinces in total mushroom export

Ontario in 2019 exported only 1/4th of its produce as fresh mushrooms whereas BC exported 63% of its production (Table 12).

Speciality mushrooms (oyster, shiitake, enoki and others) are about 2% of total production and about 2% of exported quantity (Table 12).

Like USA, only small part of the produce are processed and instead canned mushrooms are imported.

Table 12. Export of fresh mushrooms from Canada

		2017	2018	2019	2020
		***Agaricus* Fresh (HS70951)**			
BC	World	27213	31348	35019	37610
	USA	27045	31237	34760	37300
Ontario	World	10348	13182	16220	19014
	USA	10346	13181	16219	19013
Others	World	10	14	22	33
	USA	10	13	21	32
Canada	World	37571	44544	51261	56656
	USA	37400	44431	51000	56344
		Others Fresh (HS 70959)			
BC	World	311	1135	621	324
	USA	277	1091	510	277
Ontario	World	258	322	293	298
	USA	258	322	293	298
Others	World	31	3	1	8
	USA	31	2	1	8
Canada	World	600	1460	916	630
	USA	566	1415	804	583

Based on CIMT (2021)

Price of button and speciality mushroom

Price of speciality was 2 to 3 times more than button. Fluctuation in prices in button was much less and was almost stable with slight positive trend.

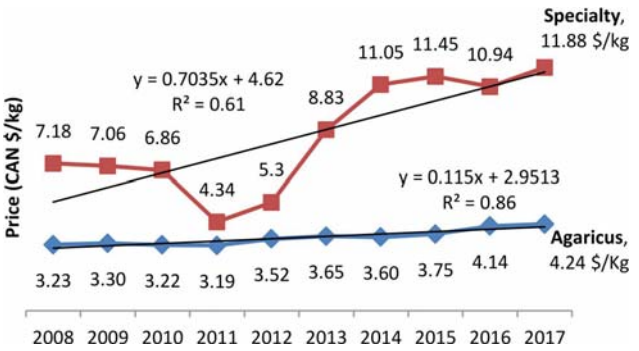

Fig. 52. Prices of button and speciality mushrooms in last decade in Canada (based on Simon Beaulieu-Fortin (2019)

Prices of speciality were less stable (R^2=0.61) (Fig. 52).

3. Others in American Continent

USA, Canada, Mexico and Brazil account for 95.3% of mushrooms in American Continent. About 92.9% of the mushroom production is in three countries viz., USA (63.8%), Canada (19.3%) and Mexico (9.8%). Mexico is considered the main producer of mushrooms in Latin America. The main producing states are: Hidalgo, the State of Mexico, Jalisco, Morelos, Puebla, Querétaro, Mexico City, Tlaxcala, and Veracruz.

Out of the remaining countries in central and southern America. Brazil, Chile and Colombia account for 5.4% and rest of the countries account for remaining 1.7% (Fig. 53).

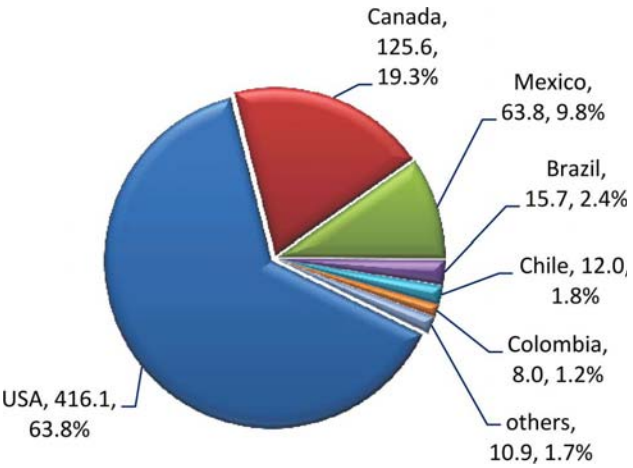

Fig. 53. Mushroom production (million kg) in American continent-2017-18 (based on Sanchez, 2018; Data of US and Canada revised)

C. EUROPE

Over 92% of mushroom production in Europe is by European Union countries even though these form only 19.1% area of Europe and 68.4% population of the Europe (Fig. 54). In rest of the Europe Russia occupies maximum space and accounts for 74.3% of the area and 19.1% of the population of Europe. It was a big consumer of mushrooms major part of which was either collected from jungles or imported.

After 2014 embargo there has been increase in button mushroom production and number of units have been established as given in next section.

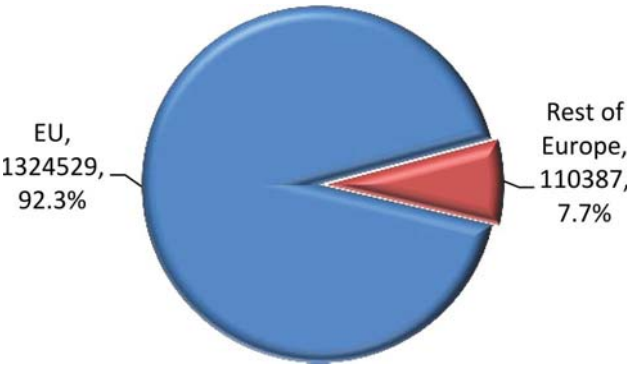

Fig. 54. EU has major share in mushroom production in Europe. Europe 2019 (Cyprus included in EU, Turkey not included in Europe)

1. European Union

Mushroom production in EU has almost stagnated around 1.2 to 1.3 million tonne in this century (Fig. 55). Countries like Poland, Russia and Turkey were in expansion mode, while others like Belgium, Holland, Hungary, and Spain are seen as mature and France, Germany, Italy, Ireland and Britain were consolidating or slowly declining (Mel O'Rourke, 2019).

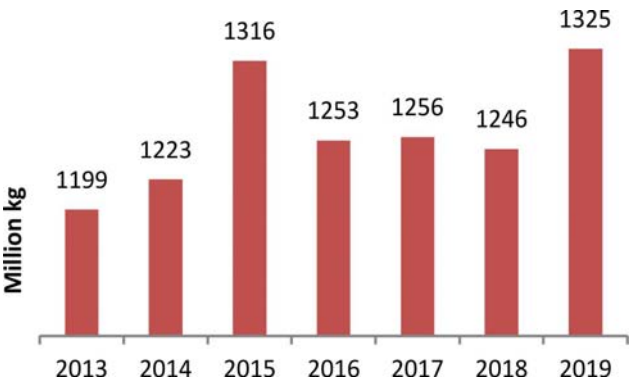

Fig. 55. Mushroom production EU (including UK) Based on FAOStat/ UN data (http://data.un.org/Data.aspx?d=FAO&f=itemCode%3A449)

Mushroom production in EU for the year 2019 was 1325 million kg (Fig. 56) and here too speciality mushrooms accounted for 3-4% of the total production. Netherlands and Poland accounted for over half of the production of EU. Rest of the Europe produced 110 million kg with Russia contributing about 48 million kg. Variation in 2018 & 2019 (Fig. 55) is mainly due to sudden increase in mushroom production data of Poland from 280 to 362 million kg in FAO Stat.

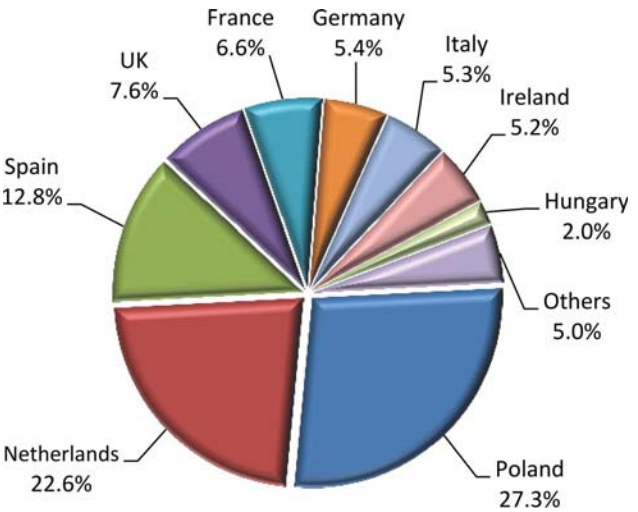

Fig. 56. Mushroom Production EU -2019 (1325 million kg) FAOStat

FAOStat and Eurostat are similar for most of the countries. However, there is Some variation in mushroom production in Netherlands vs. Poland in FAOstat and Eurostat and also as reported by others as shown in Fig. 57 (Mel O'Rourke, 2019).

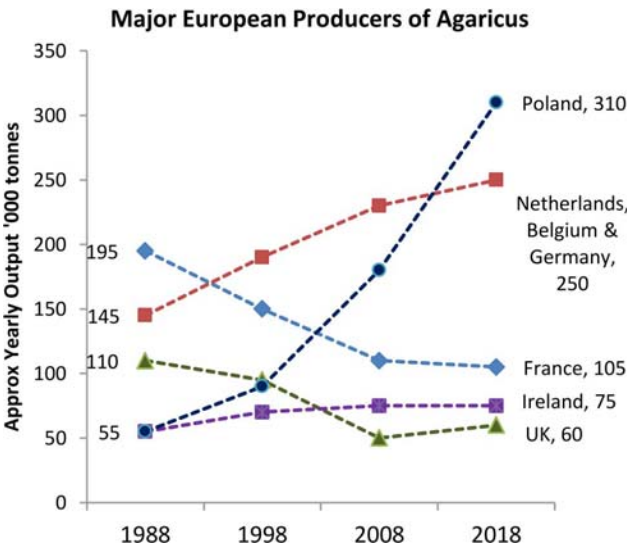

Fig. 57. Major European Producers of *Agaricus* (Based on Australian Mushroom Journal Ed-1, 2019 32-35)

Poland has become the largest mushroom producer in Europe and the largest exporter of fresh mushroom in the world. 75% of mushrooms produced in Poland goes abroad. Major reason for this was direct access to the technology of mushroom cultivation from Holland after merger with EU. Production in the phase III and low prices for mushroom offered by Polish producers were some other reasons. Despite the entry into the European Union and the rise of living standards in Poland, the labour force here is still cheaper than in the main countries. The minimum wage of women is 25% of the minimum wage in other EU. The productive capacity in Poland is now estimated at 315 -330 thousand. Tonnes. (Sakson 2020). In addition they had the raw materials through cereal production; there was plenty of labour with unemployment at over 20%, and they had an independent currency (Mel O'Rourke, 2019).

Share of speciality mushrooms in mushroom production is <4% in EU (Pers Comm : Magda) (Table 13, Fig. 58). Spain, Poland, Germany, Italy are major contributors of other mushrooms. For example in Italy in 2017 estimates were that 80% are button followed by *Pleurotus* (mostly *P.ostreatus* but also *P. eryngii*), *Cyclocybe aegerita* and, to less extent, shiitake (MyFruit 2018).

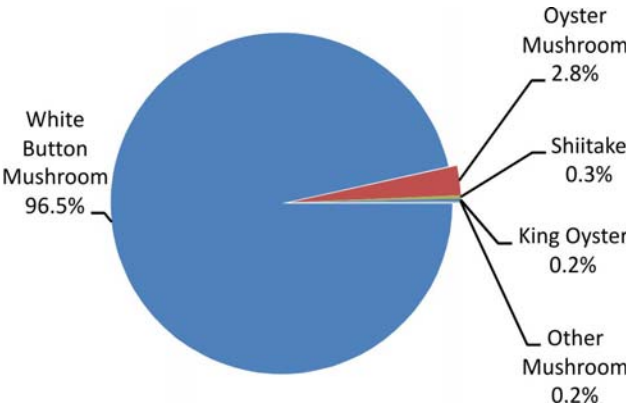

Fig. 58. Share of different species in total mushroom production in EU in 2016

Export

Poland and Netherlands are the major exporters of fresh and canned button mushroom. A large share is exported to EU (Fig. 59 & 60) and USA and these two countries are among the major exporters in the world (Table 14). Five major importing and exporting countries of fresh and canned mushroom in 2019 are as in Table 14. Poland and Netherlands export up to 75% of their produce.

The most important import country of fresh button mushrooms in the world is UK followed by Germany and imports are mainly from within EU. The US is

Table 13. Production of speciality mushrooms in some EU countries in 2016

Country	Total mushroom sales	White Button Mushroom	Oyster Mushroom	Shiitake	*Pleurotus eryngii*	Other mushrooms	Total of speciality
Poland	278000	270000	8000	260	0	0	8260
Netherlands	272000	270000	1400	600	150	0	2150
Spain	147000	130000	17000	1500	100	50	18650
France	102200	100000	1500	550	50	100	2200
Italy	75000	68000	5000	0	500	1500	7000
Germany	73100	70000	900	800	1300	100	3100
Others	347700	342000	2600	290	500	250	3640
Total EU	1295000	1250000	36400	4000	2600	2000	45000

Pers comm Magda; Ackn: Ulrich Groos

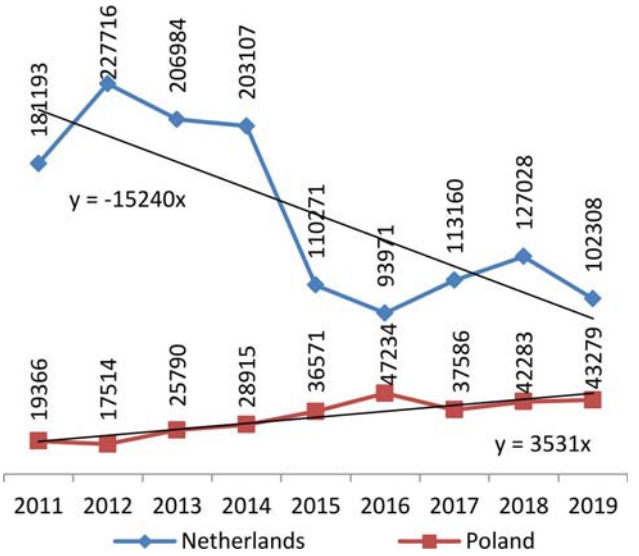

Fig. 59. Export of canned mushrooms to EU (tonne)
http://www.infochampi.eu/production-figures/
Source: Eurostat/GEPC

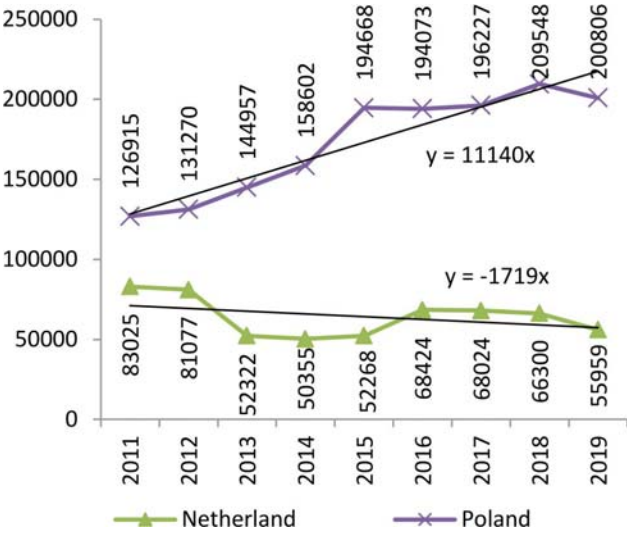

Fig. 60. Export of fresh mushroom to EU (Tonne)
http://www.infochampi.eu/production-figures/
Source: Eurostat/GEPC

Table 14. Major exporting and importing countries of fresh and canned mushrooms

Export (Fresh)		Import (Fresh)	
Country	**Qty (tonne)**	**Country**	**Qty (tonne)**
Poland	238148	UK	120528
China	125759	Germany	91206
Netherlands	78471	USA	76485
Canada	52217	France	49425
Ireland	44655	Netherlands	29222
Export (Canned)		**Import (Canned)**	
China	261614	Belgium	91808
Netherlands	130152	Germany	55627
Belgium	68135	USA	44989
Poland	66670	Russian Fed	40750
Spain	55705	France	27277

http://www.fao.org/faostat/en/#rankings/countries_by_commodity_exports

the third import country globally and meets its imports mainly from Canada and Mexico (Boon, 2018).

2. Rest of Europe

In 2019 Russia was the major producer in rest of the Europe (Fig. 61) followed by Belarus, from where produce is mostly exported. Total production in rest of the Europe in 2019 was 110 million kg (FAOStat).

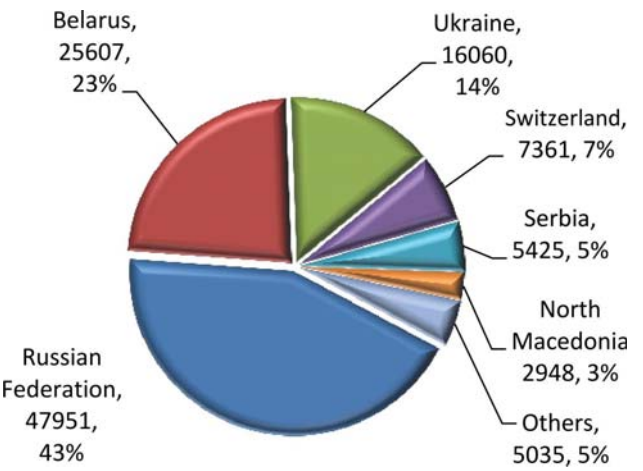

Fig. 61. Mushroom production in Rest of Europe in 2019 was 110 million kg (Source: FAOStat)

(i) Russian Union

In Russia there is rapid increase in mushroom production in last few years (Fig. 62) and about 95% share in production is of button mushroom. Until 2015 mushroom cultivation in the country was poorly developed, mainly due to the low-cost imports. In the past few years the country has seen an increase in mushrooms production as supported by government by providing soft loans and making changes in legislation (*LAN Moscow, 2018).* As per official figures, in 2012 mushroom production was 5000 tons that increased to 9680 tons in 2016 and finally reached 16000 tons in 2017. Production as reported in FAOStat in 2019 was 47951 tonne.

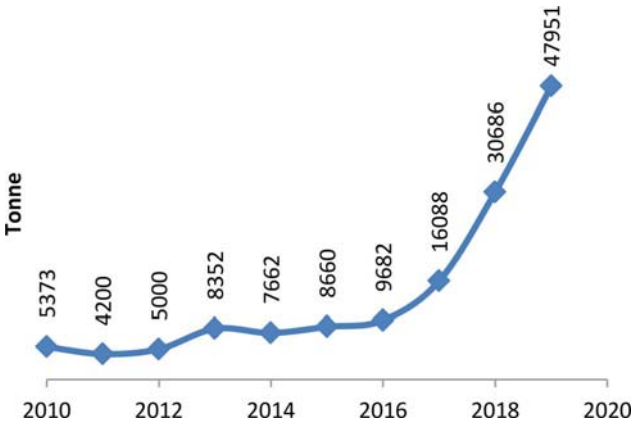

Fig. 62. Mushroom production in Russian Union. FAOstat 2021

Industrial cultivation of mushrooms in Russia is becoming more attractive: the demand greatly exceeds supply, and imported products from Poland and other EU countries are under embargo. There is a rapid decline in import of button mushroom (Fig. 63). Product embargo introduced by Russia in 2014 became the key factor influencing the development of the industry. Since then, several modern full-cycle mushroom complexes have been built. After 2014 there was a shift in government policies. The government's mushroom strategy calls for "import substitution for fresh mushrooms by 90%; for canned mushrooms by 60% and compost for growing mushrooms by 100% (Helmer, 2016).

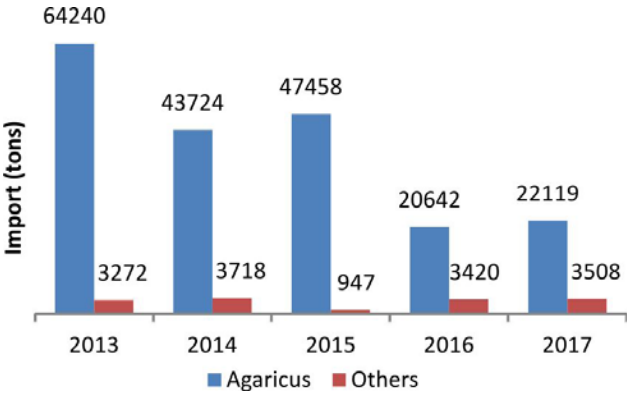

Fig. 63. Imports of fresh mushrooms into the Russian Federation (tons). Source: Russian Customs/ Ministry of Agriculture of the Russian Federation as available on net. Major countries supplying mushroom to Russia were Belarus and Poland

The per capita consumption of cultivated mushrooms in Russia, is about 1 kg per person (Devochkina *et al*., 2018). According to some estimates about half of the mushrooms consumed in Russia are fresh where as more than half mushrooms are eaten in processed form, either dried, canned, frozen, or pickled (Helmer, 2016).

(ii) Belarus

Belarus is a small country whose population consumes not more than 25% of the mushroom produced in the country by several large farms. The main customers of Belarusian farms are in the Russian Federation, with which Belarus is in the Customs Union. A special feature of the country's mushroom industry is the lack of compost in its own right - farms operate on composts imported from Poland. Only next year it is planned to open the first compost plant in the country. But the compost plant is planned to be large and will cover more than half of the compost consumption in the country (https://www.mushroom business.com/news/covid-19-belarus).

(iii) Switzerland

Around 20 mushroom farms in Switzerland cultivate brown or white champignons. Swiss

producers also grow a range of other mushroom varieties including shiitake, oyster, French horn, ram's head and shimeji mushrooms. Share of button mushroom is around 90%. Production seems to be stabilizing around 7000 tonne and the rest is imported from Netherlands, Poland and Germany, etc (Hofmann, 2016).

D. OCEANIA

1. Australia

Mushroom production data is available from Hort innovation publications and Australian Bureau of Statistics. Mushroom cultivation in Australia was first attempted in 1930s but as in other parts of the world, the industry started picking up only after world war II and Australian Mushroom Grower's Association (AMGA) was formed in 1961. At present mushroom are Australia's sixth most valuable horticultural crop and the second most valuable fresh product in the vegetable category, after potatoes (Source: ABS). The mushrooms cultivated include *Agaricus bisporus* (button, cup, flat and brown mushroom) as well as exotic mushroom varieties including shiimeji and oyster. The share of exotics is very small and the major focus is on cultivation of button mushroom which accounts for 98% of the mushrooms cultivated in the country (AMGA Report. 2010). There is growing demand for exotic, nutriceutical and wild mushrooms (e.g. shiitake, oyster, straw, etc). However, this niche market is very small.

Production of mushrooms in Australia in 1975 was 6 thousand tonne that increased to 8.3 thousand tonne in 1980, 33.1 thousand tonne in 1990, 55.1 thousand tonne in 2000 (Seymour, 2010) and about 65.1 thousand tonne in 2010. In the last decade production was between 65 to 72 thousand tonne (Hort Innovation). There was continuous increase in production from 2016 till 2019 and production peaked at 72 thousand tonne. In 2019/20 the production was 68.8 million kg (Table 15) . The industry, like in other developed economies, is faced with rising costs in labour, energy and general inputs and there is decline in the number of commercial growers (Fig. 64). Despite this, the

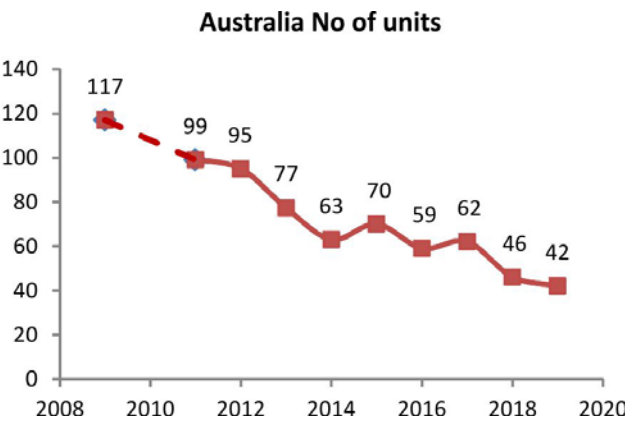

Fig. 64. Decline in number of commercial mushroom production units (Source: ABS)

Table 15. Mushroom production in Australia (Hort Innovation)

	2013	2014	2015	2016	2017	2018	2019	2020
Total Production (t)	65268	68377	65420	64276	67089	70463	72007	68823
Production Processed (t)	1958	2051	1782	1750	1764	1786	1825	1744
Fresh Export Volume (t)	62	107	94	59	62	89	71	72
Production sold as fresh(t)	63248	66219	63544	62467	65263	68588	70111	67007
Fresh Import Volume (t)	1846	1998	2384	2508	3151	3288	3839	3874
Total Fresh Supply (t)	65094	68217	65928	64975	68414	71877	73949	70800
Supply per Capita (kg)	2.82	2.91	2 .77	2.69	2.79	2.88	2.93	2.75

Data as reported by official agency Australian Bureau of Statistics is different from this
Based on data in Australian Horticulture Statistics Handbook by Hort Innovation

overall production in last decade has remained around 68 thousand tonne. As per AMGA Report 2010, the productivity of Australian mushroom growers had about doubled in the last twenty years from average yields of 18 kg of mushrooms per square metre to in excess of 35 kg for the more efficient growers.

Mushrooms are grown in most states of Australia, close to population centres in peri-urban areas. The major production areas are near Adelaide in South Australia; Melbourne Metro in Victoria and the Sydney Basin in New South Wales (Hort stat handbook). In 2019/20 the total production reported was 68823 tons out of which Victoria, New South Wales and South Australia accounted for over 83% of the production (Fig. 65).

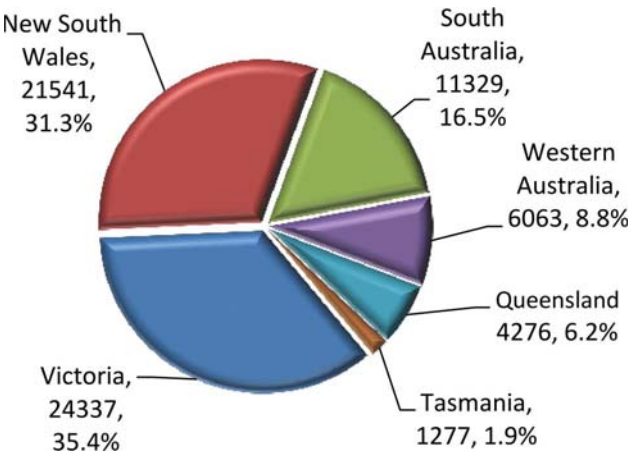

Fig. 65. State wise Mushroom production (in Tonnes) in Australia in 2019/20 as per Hort Innovation

Changes in yield were almost same in different states as per Hort Innovation. For example there was decrease in yield in all states in 2016 as compared to yields in 2015 and it was about 1.8%. In 2017 there was 4.4% increase, in 2018 5% and in 2019 about 2.2% increase in most of the states (Fig. 66). In 2019/20 Victoria and New South Wales produced 2/3rd of the mushrooms of Australia (Hort innovation data) with Victoria producing 35.4% (Fig 65).

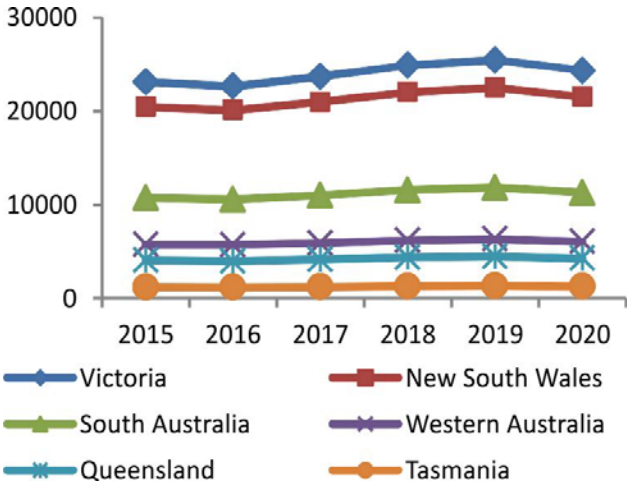

Fig. 66. Mushroom production in different regions

In last 5 year, on average 2.6% of total production in the country was processed, 0.1% of this total production was exported as fresh and 97.3% of the total production was sold as fresh. About 4.7 % of total fresh mushrooms was in the form of imports and 95.3 % came from local produce (Table 15). Of 73949 t total fresh supply in 2018/19, 53586 (72%) was sold as retail whereas 20363 t (28%) went to food services (Hort Innovation)

FAOSTAT VS ABS

FAOSTAT for Australia exactly matches Australian Bureau of Statistics (ABS) for all the years. Australian Horticulture Statistics Handbook by Hort Innovation (HI) is reporting about 40% more

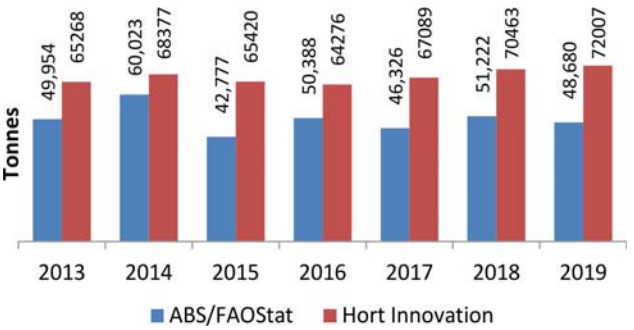

Fig. 67. Mismatch between FAOSTAT and Hort Innovation data

production than ABS if we look into the data of last five years (Fig. 67).

However, if we look into state-wise data as reported by ABS, % share of Victoria in production is much higher (43% as compared to 35% by HI) (Fig. 68 & 69). If we compare state wise production in last few years between Hort Innovation and ABS, it can be seen that ABS has projected much lower production in New South Wales as compared to Victoria (Fig. 69).

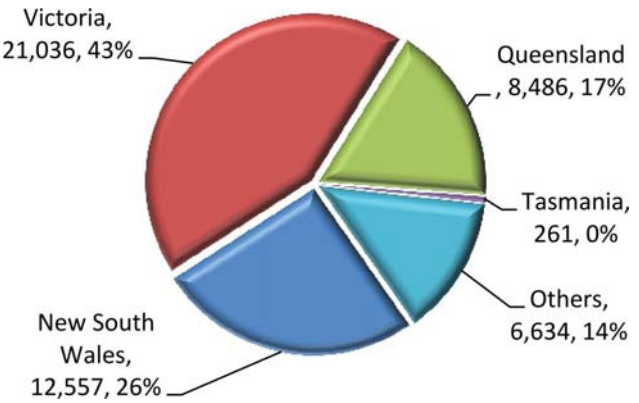

Fig. 68. State wise Mushroom production (in Tonnes) in Australia in 2019/20 as per Australian Bureau of Statistics (ABS)

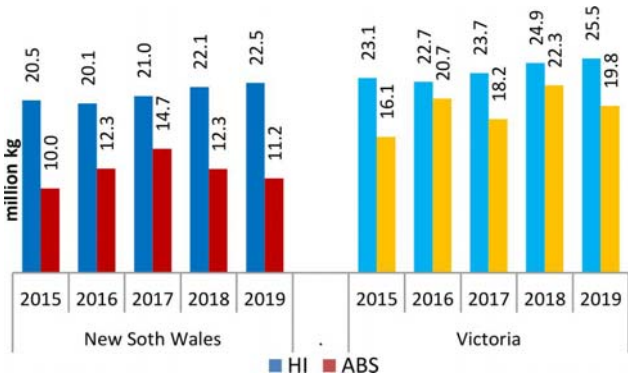

Fig. 69. Mushroom production in NSW and Victoria as per HI and ABS in Australia

Even though according to both ABS and HI New South Wales and Victoria are major contributors, but on average production reported from 2015-20 by ABS was 43 percent less than HI in NSW and was only 18 % less in Victoria.

As per details available in ABS, Greater Sydney in NSW, Port Phillip and Western Port in Victoria, and South East Queensland in Queensland were the major areas of production (Fig. 70-72).

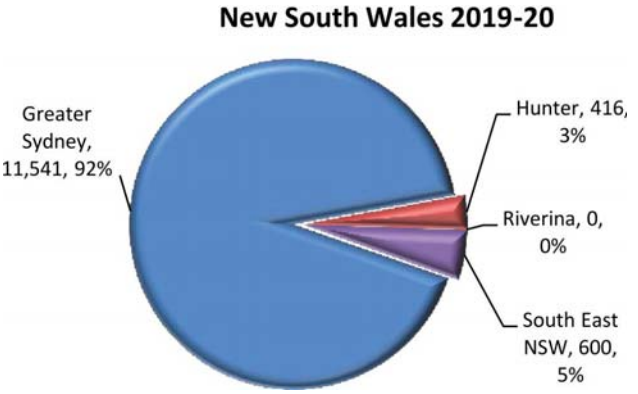

Fig. 70. Region wise production in New South Wales in 2019/20 as per ABS

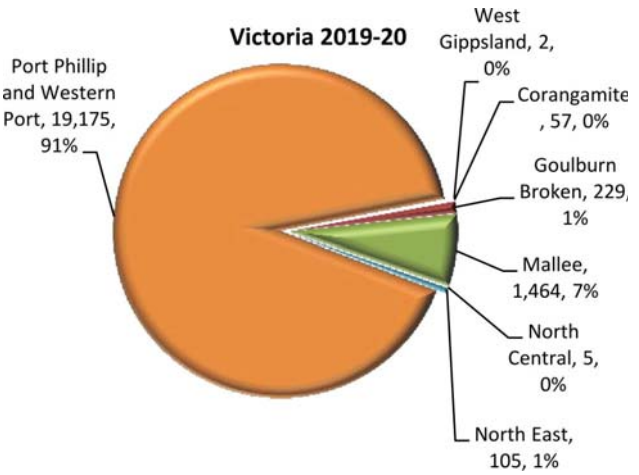

Fig. 71. Region wise production in Victoria in 2019/20 as per ABS

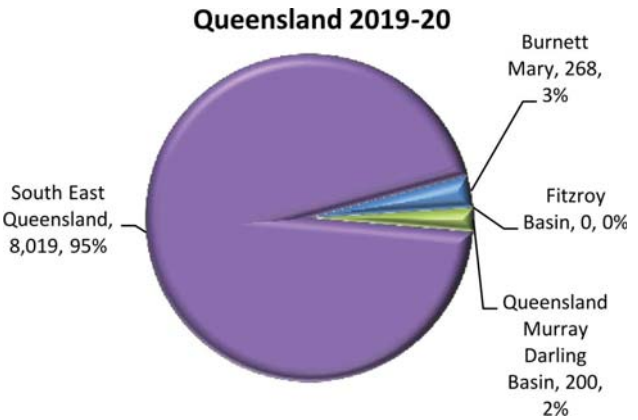

Fig. 72. Region wise production in Queenland in 2019/20 as per ABS

Mushroom Import/Export

Australia is a net importer. The fresh mushrooms imported and exported in last decade are shown in Fig. 73.

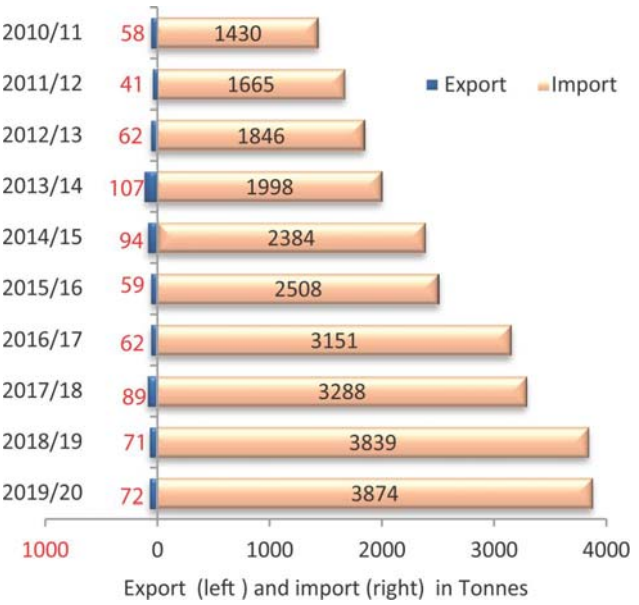

Fig. 73. Export/ import of fresh mushrooms in Australia (based on Hort innovation year books)

About 3 to 4% of local fresh consumption was met from fresh imports mainly from South Korea, China and Taiwan (Table 16, Fig. 67). There was negligible export of fresh mushrooms (50-100 tonne) in different years (Table 17, Fig. 74).

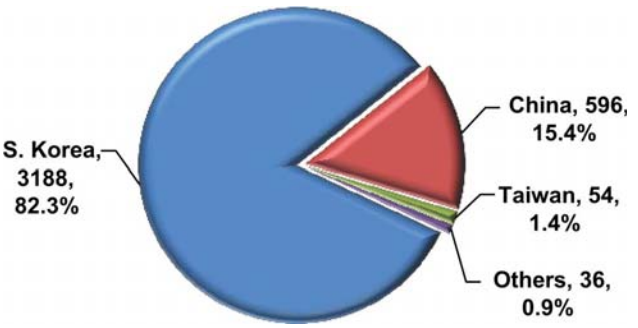

Fig. 74. Country-wise import of fresh mushrooms in 2019/20 (Hort Innovation)

Australia imported around 650 tonne dry and 4400 tonne preserved mushrooms and exported a small fraction of this in last five years (Table 18)

In 70s the production was low and large scale import of canned mushrooms was the mode to meet

Table 16. Imports of Fresh mushroom (2013-20)

	2013	2014	2015	2016	2017	2018	2019	2020
S. Korea	1470	1636	1823	2033	2561	2709	3160	3188
China	330	316	506	377	486	526	574	596
Taiwan	39	28	30	30	18	16	17	54
Others	7	18	25	68	86	37	88	36
Total	1846	1998	2384	2508	3151	3288	3839	3874

(based on Hort innovation)

Table 17. Export of fresh mushrooms- country wise

	2013	2014	2015	2016	2017	2018	2019	2020
Fiji				7	12	22	23	21
Nauru	19	49	26	4	4	9	11	12
Brunei	6	8	12	16	16	14	12	14
Papua New Guinea	13	15	15	13	15	19	9	8
Others	24	35	41	19	15	25	16	17
Total	62	107	94	59	62	89	71	72

Table 18. Import of dried and preserved mushrooms 2014-2020

	Dried (tonne)		Preserved (t)	
	Export	Import	Export	Import
2019/20	95	667	58	4384
2018/19	25	709	108	4398
2017/18	88	630	18	4142
2016/17	21	586	41	4315
2015/16	2	675	91	4645
2014/15			12	4217
2013/14	37	630	41	4330

(Based on : Australian Horticulture Statistics Handbooks)

the demand of the mushroom in the country. Imports have fallen from approximately 50 per cent of the market in the mid 1970's to 10 per cent by 2005/06. In 2019/20 3874 tonne (3%) fresh mushrooms were imported in addition to import of 4384 tonnes of preserved mushrooms and 667 tonnes of dried mushrooms. The fresh imports as mentioned earlier were mostly from South Korea, China and Taiwan. These countries are major producers of mushrooms other than *Agaricus*. Like in other countries, the consumption of processed mushrooms was high in 70s and presently fresh mushrooms are mainly consumed.

Consumption

In the 1970s, most mushrooms eaten in Australia were sold in cans. Today, about 97 per cent of domestic production is eaten as fresh mushrooms, with only small quantities going to processing. Australian annual per capita mushroom consumption jumped from 0.6 kg in 1974 to over 3.0 kg at present.

2. New Zealand

The New Zealand mushroom industry is a buoyant and expanding one, although it is small in comparison to Australia. In 2003, production was 8,300 tonnes (Grogan, 2004). Button mushrooms were the focus of New Zealand's mushroom industry for nearly 50 years. Today a range of edible fungi are grown, including shiitake and oyster mushrooms. Mushrooms were first grown for sale in New Zealand in the 1930s. By the 1960s, growing techniques had improved, and an industry began. Most mushrooms grown in New Zealand are sold locally, fresh. The three types on sale – white button mushrooms, Swiss browns and Portobello flats – are all versions of the same species, *Agaricus bisporus*. (Wassilieff. 2008).

East Africa

Africa constitutes at least 25% of the total mushroom biodiversity worldwide but contributes barely 0.4% of total mushroom sales and new mushroom products on the global market. Yet mushrooms are well known in most indigenous African recipes (Mpeketula, 2008) and, at the onset of the rainy seasons, it is customary to find rural people across many African countries (for example, Cameroon, Nigeria, Malawi, Ghana, Benin Republic, Togo, Uganda, Ethiopia, Kenya, Equatorial Guinea and Zimbabwe) going out to search mushrooms from decaying wood and palm trees (Yongabi *et al*., 2004). So far, African mushroom growers have only succeeded in growing *Pleurotus* species (Oyster mushrooms) especially *Pleurotus ostreatus, Pleurotus sajo-caju* and *Pleurotus pulmonarius,* on corn cobs, rice husks, maize bran and sawdust. In Namibia, Malawi and Zimbabwe, the Zero Emission Research Initiative (ZERI, www.zeri.org) program has demonstrated success with the cultivation of *P. ostreatus* on a wide range of substrates including water hyacinth (Yongabi, 2014).

Many African countries are growing and attempting mushroom cultivation though adequate data is not available.

South Africa

In South Africa about 21000 tonnes per year (2018) mushrooms are produced with half the mushroom producers in Gauteng, 28% in the Western Cape, and 17% in KwaZulu-Natal. Some South African mushrooms are exported, mostly to neighbouring countries such as Namibia

and Mauritius (southafrica.co.za › mushroom-production).

In South Africa the white button and brown mushrooms are mainly grown. South Africans are finding more and more interest in Exotic Mushrooms as well as medicinal mushrooms. Commercial cultivation of Exotic Mushrooms in South Africa is still in the infant years. Less than 5% of the mushroom market is taken up by so called exotic mushrooms, including *Pleurotus* spp (Oyster mushrooms) and *Lentinula* spp (Shiitake) (Marock, 2017).

Final Output

Data procured from major mushroom producing countries or accessed from the papers/databases available was pooled. Based on data from different sources, world mushroom production in 2018-19 was estimated as 43 million tonne with *Lentinula edodes* (shiitake) contributing 26%, *Auricularia* spp 21% *Pleurotus ostreatus* 16%, *Agricus bisporus* (button) 11%, *Flammulina* 7%, *P. eryngii* (king oyster) 5%, Paddy straw mushroom 1% and others 13% (Fig 75). Considering the growth patterns in major mushroom producing countries it is estimated that global production may surpass 50 MT by 2025.

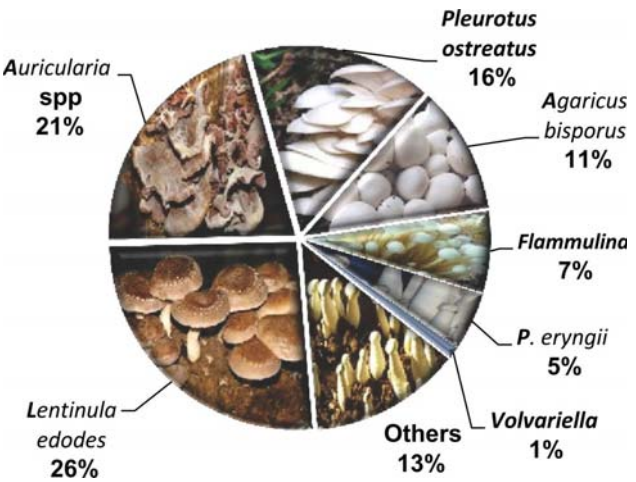

Fig. 75. Global mushroom production 2018-19

Other important contributors to world mushroom production were *Agrocybe aegerita, Pholiota nameko, Tremella fuciformis, Hypsizygus marmoreus,* etc. Production in developed countries is on decline or has reached plateau whereas it is increasing in India and many other countries of the region.

ACKNOWLEDGEMENTS

We acknowledge help from Dr Won Sik Kong (NIHHS, RDA, S. Korea), Ms Meilian Yu (SAAS, China), Ms Magda V (Mycelia, Belgium), Er. Ulrich Groos (Director, HLP, Germany), Dr Daniel J Royse (USA), Dr Kovrova, Irina (ESS, FAO), Mr Graham J (Canstat, Canada) and other resources of the net from where the information was taken.

REFERENCES

1. Amin, S.R., N.C. Sarker, A. Khair and N. Alam. 2007. Detection of novel supplements of paddy straw substrate on oyster mushroom cultivation. *Bangladesh Journal of Mushroom* **1:** 33-37.

2. Australian Bureau of Statistics (ABS). 2020. https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/2019-20#data-download

3. Australian Horticulture Statistics Handbook-Vegetables (Hort Innovation) 2014/15; 2015/16; 2016/17; 2017/18; 2018/19 and 2019/20

4. AMGA. 2010. The Australian Mushroom Growers Association. Submission to The Productivity Commission Inquiry into the Australian Government Research and Development Corporations Model. June 2010. https://www.pc.gov.au/inquiries/completed/rural-research/submissions/sub155.pdf

5. Boon, J.K. 2018. Mushrooms: Poland gaining more and more ground. https:// www.freshplaza.com/article/9032300/

6. Cameron, R.J. 1978. Year book Australia No 62, 1977 & 1978. Australian Bureau of Statistics, Canberra, Australia. Pp 319-320.

7. CEFA. https://www.cefa.org.cn/

8. Chang, S.T. 2005. Witnessing the development of the mushroom industry in China, In: Tan Q., Zhang J., Chen M., Cao H., Buswell J. A. (eds.) Mushroom Biology and Mushroom Products. Shanghai Xinhua Printing Co., Ltd. Shanghai, China. Acta Edulis Fungi, Vol. 12, pp. 3-19.

9. Chang, S.T. 2006, The World Mushroom Industry: Trends and Technological Development. International Journal of Medicinal Mushrooms, Vol. 8, pp. 297-314 (2006).

10. Devochkina, N.L., L.G. Dugunieva, A.F. Razin, M.I. Ivanova and R.D. Nurmetov. 2018. Investment attractiveness of the industrial mushroom production *Economics of Agriculture of Russia* 11 pp 52-59.

11. Devochkina, N., R. Nurmetov and A. Razin. 2019. Economic assessment of the development potential of mushroom production in the Russian Federation. International Conference on Sustainable Development of Cross-Border Regions, IOP Publishing, IOP Conf. Series: Earth and Environmental Science 395 (2019) 012076.

12. Easin, Mohammad Nura, R. Ahmed, M.S. Alam, Md. S. Reza, K.U. Ahmed. 2017. Mushroom Cultivation as a Small-Scale Family Enterprise for the Alternative Income Generation in Rural Bangladesh. *International Journal of Agriculture, Forestry and Fisheries.* **5(1):** 1-8.

13. Edward, White. 2017. Fungus Among Us: The History of Mushrooms in Taiwan. https:/ /international.thenewslens.com/article/60211

14. Export of mushrooms from Canada 2019. http:/ /www.fao.org/faostat/en/#data/TM

15. FAOSTAT.2021. http://www.fao.org/faostat/ en/#data/TM

16. Ferdousi, Jannatul, Z.A. Riyadh, Md. I. Hossain, S.R. Saha, and Mohammad Zakaria. 2019. Mushroom Production Benefits, Status, Challenges and Opportunities in Bangladesh: A Review. *Annual Research & Review in Biology* **34(6):** 1-13.

17. Gamage, S. and Ohga, S. 2018. A Comparative Study of Technological Impact on Mushroom Industry in Sri Lanka: A Review. *Advances in Microbiology* **8:** 665-686.

18. Ghanbari. J., H.R. Pourianfar, M.S. Nabavi and E.M. Mendi. 2015. A comparative study of agronomic characteristics in several Iranian wild isolates of the button mushroom, *Agaricus bisporus. International Journal of Advanced Research* **3(2):** 230-235.

19. Grogan, H. 2004. New Zealand Mushroom Industry. *The Mushroom Journal* **656:** 19-24.

20. Gyõrfi, J. 2010. Mushroom biology, mushroom growing, Mezõgazda Kiadó, Budapest, p. 309-313.

21. Helmer, J. 2016. http://johnhelmer.net/more-import-substitution-tips-in-wartime-which-side-of-the-russian-mushroom-will-make-a-fortune/

22. Ho, Thi Minh Hop. 2017. In ' VIII International Agriculture Symposium "AGROSYM 2017": book of abstracts' p1228.

23. Hofmann, H. 2016. (https://www.zeit-fragen.ch/en/archives/2016/no-2122-10-october-2016/swiss-cultivated-mushrooms-fresh-harvest-all-year-round.html)

24. Hort Innovation. http://horticulture.com.au/wp-content/uploads/2016/09/Horticulture-Statistics-Handbook-2015-16-Other.pdf

25. http://horticulture.com.au/growing-innovation/source-mushroom/

26. http://www.australianmushrooms.com.au/about-mushrooms/history-in-australia/

27. Iran. 2020. https://www.agroberichtenbuitenland.nl/landeninformatie/iran/achtergrond/bedekte-teelten_sp

28. Jeznabadi, E.K., M. Jafarpour and S. Eghbalsaied. 2016. King oyster mushroom production using various sources of agricultural wastes in Iran. *Int J Recycl Org Waste Agricult* **5:** 17-24.

29. koreittimes.com. 2013. https://www.freshplaza.com/article/2109987/korea-eu-mushroom-export-on-the-rise/

30. Kószó, S. 1997. Growing king oyster mushrooms, Hungarian Mushroom, No. 2, p. 12-13.

31. LAN Moscow. 2018. https://www.agroberichtenbuitenland.nl/actueel/nieuws/2018/04/19/big-prospects-for-mushroom-growing-in-the-russian-federation.

32. Li, Yu. 2012. Present development situation and Tendency of edible mushroom industry in China. Proceedings of the 18th congress of ISMS pp 3-9.

33. Li, M. and J.L. Hu. 2014. Study on Survival Strategies of Farmers Engage in Small-Scale Household Cultivation of Edible Mushrooms: Take Shandong Province as an Example. *Modern Economy* **5:** 1092-1100. (http://dx.doi.org/10.4236/me.2014.512100)

34. MAFF. Ministry of Agriculture, Forestry and Fisheries, https://www.maff.go.jp/j/tokei/kouhyou/tokuyo_rinsan/index.html

35. MAFRA. Ministry of Agriculture Food and Rural Affairs. https://www.mafra.go.kr

36. MAGMPEM. https://financialtribune.com/articles/economy-domestic-economy/94195/iran-mushroom-production-estimated-to-increase-by-66#:~:text=Taqavi%20added%20that%20currently%20900,Europe's%20average%20of%204%20kilograms.

37. Marock, Dave. 2017. https://www.lichengroup.co.za/basics-you-need/ Growing Mushrooms – Basics Of What You Need To Know 17 Nov 2017 By Dave Marock

38. MDI (Mushroom Development Institute).Annual Report 2018-19, Savar, Dhaka; 2019.

39. Mel O'Rourke. 2019. The success of the European Mushroom Industry. *Australian Mushroom Journal* **1:** 32-35.

40. Mostak Ahmed, N. Abdullah, K.U. Ahmed and M.H.M. Borhannuddin Bhuyan. 2013. Yield and nutritional composition of oyster mushroom strains newly introduced in Bangladesh. *Pesq. agropec. bras., Brasília*, 48 (2): 197-202

41. Mpeketula, P.M.G. 2008. Indigenous mushroom species cultivation, processing and utilization for food security and conservation. *National Research Council of Malawi, Conference Proceedings*. 95-105

42. Mushroom Growers' Survey, 2020 https://www150.statcan.gc.ca/n1/daily-quotidien/210623/dq210623e-eng.htm

43. MyFruit. 2018. December https://www.myfruit.it/prodotti/2018/03/funghi-coltivati-produzione-stabile-italia.html

44. MyFruit. 2018. Mar 23. Funghi coltivati, produzione stabile in Italia [Cultivated mushrooms, stable production in Italy]

45. Nostratrabadi, S., S. Vinogradov and B. Almadi. 2020. Mushroom farming in Iran: a case study of ten Iranian mushroom companies. Vadyba / *Journal of Management* **36(2):** 111-117.

46. Raut Jay Kant. 2019. Current Status, Challenges and Prospects of Mushroom Industry in Nepal. International Journal of Agricultural Economics. **4(4):** 154-160. doi: 10.11648/j.ijae.20190404.13

47. Rodriguez Estrada, A.E. and D.J. Royse. 2005. Cultivation of *Pleurotus eryngii* in bottles, *Mushroom News* **53(2):** 10-19.

48. Rodriguez Estrada, A.E. 2008. Molecular phylogeny and increases of yield the antioxidants selenium and ergothioneine in Basidiomata *Pleurotus eryngii*, Dissertation, The Pennsylvania State University, Department of Plant Pathology, p. 237.

49. Rosmiza, M.Z., W.P. Davies, C.R. Rosniza Aznie, M.J. Jabil and M. Mazdi. 2016. Prospects for Increasing Commercial Mushroom Production in Malaysia: Challenges and Opportunities. *Mediterranean Journal of Social Sciences,* 7: 406-415. *ISSN 2039-2117 (online).*

50. Royse, D.J. 2014. A global perspective on the high five: *Agaricus, Pleurotus, Lentinula, Auricularia & Flammulina*. In Proceedings of the 8th International Conference on Mushroom Biology and Mushroom Products (ICMBMP8), New Delhi, India, 19–22 November 2014 (Eds: Manjit Singh *et al*.). Vol. I: pp 1-6.

51. Royse Daniel, J., J. Baars and Q. Tan. 2017. Current Overview of Mushroom Production in the World. In *Edible and Medicinal Mushrooms: Technology and Applications*, First Edition. Edited by Diego Cunha Zied and Arturo Pardo Giménez. John Wiley & Sons Ltd. pp 5-13.

52. Royse, D.J., Q. Shen and C. Mcgarvey. 2005. Consumption and production of recently domesticated edible fungi in the United States with a projection of their potential In: Tan, Q., Zhang, J., Chen, M., Cao, H., Buswell, J. A. (eds.) 'Mushroom Biology and Mushroom Products', Shanghai Xinhua Printing Co., Ltd. Shanghai, China. *Acta Edulis Fungi* **12:** 331-337.

53. Sakson, N. 2020. https://www.umdis.org/en/which-allowed-poland-to-become-a-leader-in-the-production-of-mushrooms-in-europe/.

54. Sanchez, J.E, D.C. Zied and E. Alberto. 2018. Edible Mushroom Production in the Americas. Keynote speech in " 9th International Conference on Mushroom Biology and Mushroom Products" held at Shanghai, China from 12 to 15 Nov. 2018. Abstracts of 9th ICMBMP pp 2-11.

55. Seymour, G.. 2010. What's Really Involved in Cut-through Consumer Promotion -The Mushroom Industry Experience. Presentation at AMGA. (Slide 23). https://www.pma-anz.com/userfiles/files/thu%20p3%201230%20seymour.pdf

56. Sharma, V.P., S.K. Annepu, Y. Gautam, M. Singh and S. Kamal. 2017. Status of mushroom production in India. *Mushroom Research* **26 (2):** 111-120.

57. Simon Beaulieu-Fortin. 2019. Economic Profile of the Mushroom Industry in Canada. Statistics

Canada – Catalogue no. 21-004-X2019001. (https://www150.statcan.gc.ca/n1/en/pub/21-004-x/2019001/article/00001-eng.pdf?st=l15GlCV3)

58. Singh, M., S. Kamal and V.P. Sharma. 2017. Status and trends in world mushroom production-I. *Mushroom Research* 26**(1):** 1-20.

59. Singh, M., S. Kamal and V.P. Sharma. 2018. Status and trends in world mushroom production-II -Mushroom production in Japan and China. *Mushroom Research* **27(1):** 1-25.

60. Soylu MK and Kang M. 2016. Mushroom Cultivation in South Korea. Turkish Journal Of Agriculture - Food Science And Technology, **4(3):** 225-229

61. Statistics Canada. 2020. https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=assembleDESurv&DECId=469751&RepClass=576&Id=1272849&DFId=817756.

62. Statistics Canada. 2021. Accessed on 21.06.2021. Table 32-10-0356-01 Area, production and sales of mushrooms, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210035601

63. Timothy, P. McCarty. 2010. Mushrooms-Industry & Trade Summary. United States International Trade CommissionOffice of Industries Publication ITS-07, June 2010, Control No. 2010002. 39p+23p annexures.

64. UN data. 2020. http://data.un.org/Data.aspx?d=FAO&f=itemCode%3A449

65. USDA. https://usda.library.cornell.edu/concern/publications/r781wg03d?locale=en.

66. USDA.https://www.ers.usda.gov/data-products/vegetables-and-pulses-data/vegetables-and-pulses-yearbook-tables/.

67. Vedder, P.J.C. and V. den Munckhof-Vedder, M. 2020. Modern Mushroom Growing Harvesting. p32, p50 (448p).

68. Vietnam. 2019. https://sggpnews.org.vn/business/vietnam-boosts-cultivation-exports-of-mushroom-82526.html).

69. Wassilieff Maggy. 2008. 'Mushrooms and other cultivated fungi - Mushroom industry', Te Ara - the Encyclopedia of New Zealand, http://www.TeAra.govt.nz/en/mushrooms-and-other-cultivated-fungi/page-1.

70. Yongabi, A. and Kenneth. 2014. Current Developments in Mushroom Biotechnology in Sub-Saharan Africa. WSMBMP Bulletin 11: 4-13.

71. Yongabi, K., D. Martinez-Carrera and M. Agho. 2004. Ethnomycological studies on wild mushrooms in Cameroon, Central Africa. *Micologia Aplicada International* **16(2):** 34-36. Available at http://micaplint.fws1.com .

72. Yongabi, K.A. 2004. Studies on the use of medicinal plants and macrofungi (Lower Plants) in water and wastewater purification. *Proceedings of an International E-conference organized by the International Organization for Biotechnology and Bioengineering (IOBB),* Sweden, June 14-25.

73. Yoo Young Bok, Min Ji Oh, Youn Lee Oh, Pyung G S, Kab Yeul Jang, and Won Sik Kong. 2016. Development trend of the mushroom industry. *J. Mushrooms*. **14(4):** 142-154; http://dx.doi.org/10.14480/JM.2016.14.4.142

74. Zheng. 2020. https://www.freshplaza.com/article/9282190/chinese-export-of-edible-fungi-greatly-declined-due-to-covid-19-pandemic/.