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Relative distribution of minerals in the pileus and stalk of some selected edible mushrooms[1]

Latifah Abdol Latiff,[a] Abu Bakar Mohd Daran[a] & Abu Bakar Mohamed[b]

[a]*Centre for Foundation Studies in Science, University of Malaya, 59100 Kuala Lumpur, Malaysia*
[b]*Department of Botany, University of Malaya, 59100 Kuala Lumpur, Malaysia*

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The mineral contents of seven species of edible mushrooms were investigated in this study. Four out of the seven species of edible mushrooms were studied in parts, i.e. the pileus and stalk while the other three species were studied as whole mushroom (no distinct stalk and pileus). In all the four species studied, only six (Na, As, Rb, Sb, Zn and Co) elements were found to be distributed in both the pileus and stalk. The elements Mn, Na, Rb, Fe and Zn are present in large quantities, i.e. at levels of 10 mg/kg and above. It was also observed that there is an obvious inverse relationship between the Na and Rb concentrations, notably in the species *P. sajor-caju*, *A. bisporus* and *L. edodes*. The average distribution ratio of minerals in the pileus and stalk for all the four species showed that the mineral's 'preferred residence' is in the pileus, with the exception of Sb. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

Various edible mushrooms are appreciated for their pleasant flavour and their biting texture. In general, their fruiting bodies, on a dry weight basis contain about 39.9% carbohydrate, 17.5% protein, 2.9% fats with the rest constituting the minerals. There have been a few reports on the elemental (mainly metals) analysis of some species of edible mushrooms and among them are: the study of heavy metal accumulator/collectors as in the species *Pleurotus sajor-caju* and *Pleurotus ostreatus* (Yasui *et al.*, 1988); the translocation of heavy metals into the mushroom by altering the metal concentration in the substrate (Jain *et al.*, 1988); major and trace elements in some edible Thai and Norwegian mushroom (Surinrut *et al.*, 1987); the effect of mineral supplement on the organic and mineral compositions of various mushroom types (Levai, 1988); the variation of the trace mineral (Cr, Co, Ni and Zn) contents in three wild edible mushrooms (Alofe, 1991). We have analysed the elemental contents of seven edible mushrooms, one of which was in a tablet form which was sold commercially as 'Ganoderma'. Our main aim is to study the factors that may influence the distribution of the minerals in the species studied and to see if there is a marked preference for certain minerals to be in a particular part of the mushroom, e.g. the pileus or the stalk.

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MATERIALS AND METHODS

Seven species of edible mushrooms, namely *Pleurotus sajor-caju, Agaricus bisporus, Auricularia auricula, Lentinula edodes, Termitomyces* sp., *Schizophyllum commune* and *Ganoderma* spp. were selected for this work. The first four were purchased from the local supermarket, *Termitomyces* sp. was collected from Pasoh Forest Reserve, Negeri Sembilan, *S. commune* was carefully picked from the bark of rubber trees and *Ganoderma* spp. (in the form of a tablet) was obtained from a company, Chuan Long Sdn. Bhd. All the species, except for *S. commune, A. auricula* and *Ganoderma* spp., which do not have a distinct stalk, were separated into the pileus and stalk.

After separating out the pileus and the stalk, the mushrooms were dried in the oven at 104°C for 4 h. They were then cut into small pieces and were finely ground inside a pre-cleaned porcelain dish. The homogenized samples, each weighing about 200–600 mg were then placed in three separate polyethylene vials (2/5 dram).

The National Bureau of Standard Coal Ash (SRM 1632a) was used as a standard. A duplicate of the standards was used. All vials were then heat sealed and placed inside an aluminium container before being transferred to the reactor, the Malaysian Atomic Energy Unit (PUSPATI) TRIGA MK II research reactor with a thermal flux of 4×10^{12} n/cm^2/s. The short irradiation facility using a pneumatic transfer system

Table 1. Concentrations of elements (ppm) obtained (by INAA) in seven species of mushrooms

Elements	Concentrations (ppm)										
	1A	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5**	**6**	**7**
Mn	17	9	—	—	29	22	30	49	—	77	62
La	—	0.11	—	—	0.42	0.20	3.15	3.50	0.95	2.06	1.65
Cl	—	—	—	—	—	—	0.0012	0.0006	—	0.02	0.0059
Br	0.5	0.4	6.1	9.4	0.4	0.4	16.6	10.9	98.5	0.6	6.1
Na	62	51	1333	1616	102	71	119	76	92	370	491
Th	—	—	—	—	—	—	3.79	3.30	0.51	0.24	0.37
K	5.38	3.49	9.10	—	—	—	1.38	0.50	1.46	—	—
Cr	1.8	1.5	1.6	1.3	1.3	—	1.9	1.9	2.7	2.3	3.8
As	0.2	0.2	2.0	2.1	0.3		0.8	0.6	0.8	0.2	0.3
Rb	237	104	14	10	58	34	126	44	125	22	15
Sb	0.11	0.23	0.20	0.17	0.07	0.11	0.14	0.43	0.35	0.15	0.27
Fe	100	—	—	—	104	—	1216	1061	418	865	1073
Zn	118	53	99	86	93	57	259	117	67	23	22
Co	0.22	0.20	0.19	0.10	0.27	0.25	0.35	0.45	0.35	0.52	0.64

1: *P. sajor-caju.*
2: *A. bisporus.*
3: *L. edodes.*
4: *Termitoyces* sp.
5: *S. commune.*
6: *A. auricularia.*
7: *Ganoderma* spp.
A: Pileus.
B: Stalk.

(PTS) was used to detect elements having radionuclides that are short-lived, for example Mg, Cl, Mn and K. To detect elements with longer life-times, the samples were irradiated for 10 h and cooled for 2 weeks before the measurement was made.

The gamma-ray activities of the samples were measured with a horizontal Hypergermanium detector, coupled to a 4096 channel pulse height analyser. The energy resolution is 1.90 keV at 1332 keV gamma-ray emission of ^{60}Co. Peaks were identified and quantified by a PDPP combus computer that was connected to the system.

RESULTS AND DISCUSSION

The elemental contents of the seven selected species of edible mushrooms, determined by the method of Instrumental Neutron Activation Analysis (INAA) are shown in Table 1. A total of 14 elements, i.e. Mn, La, Cl, Br, Na, Th, K, As, Rb, Fe, Zn, Cr, Sb and Co, were detected. For four species: **1** (*P. sajor-caju*); **2** (*A. bisporus*); **3** (*L. edodes*) and **4** (*Termitomyces* sp.), the analysis was done on both the pileus and the stalk (pileus, A; stalk, B), while the species **5** (*S. commune*); **6** (*A. auricularia*) and **7** (*Ganoderma* spp.) which have no distinct stalk were analysed as whole mushrooms.

The mineral distribution in the species studied showed that Mn, Na, Rb, Fe and Zn are present in a large quantity, i.e. at levels of 10 mg/kg and above. This is clearly illustrated in the three-dimensional plot of concentration versus the mineral elements for the four different species, i.e. **1**, **2**, **3** and **4**, used (see Fig. 1). The different species showed different distributions of minerals; some are more concentrated in the pileus and some in the stalk. The term 'preferred residence' will be used here, and a measure of the 'preferred residence' will be expressed in terms of the ratio of the mineral concentration in the pileus to the stalk. For the case where a full 'preferred residence' is available, the ratio given is either +1 (reside fully in the pileus) or −1 (reside fully in the stalk). If the distributions of minerals are in both the pileus and stalk, then the ratio is between 0 and 1. In the absence of mineral considered, no

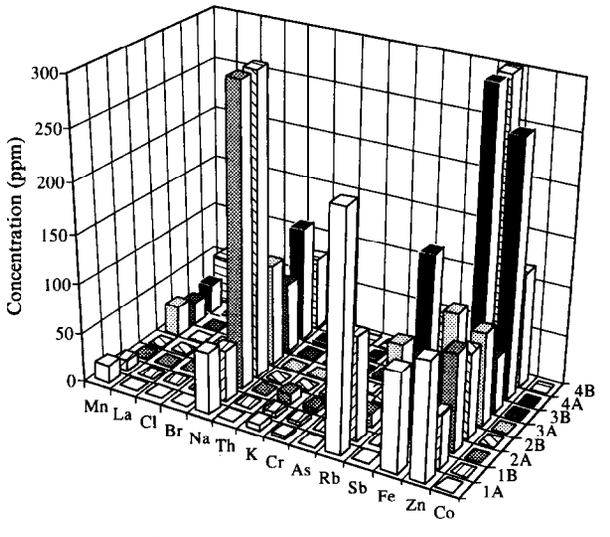
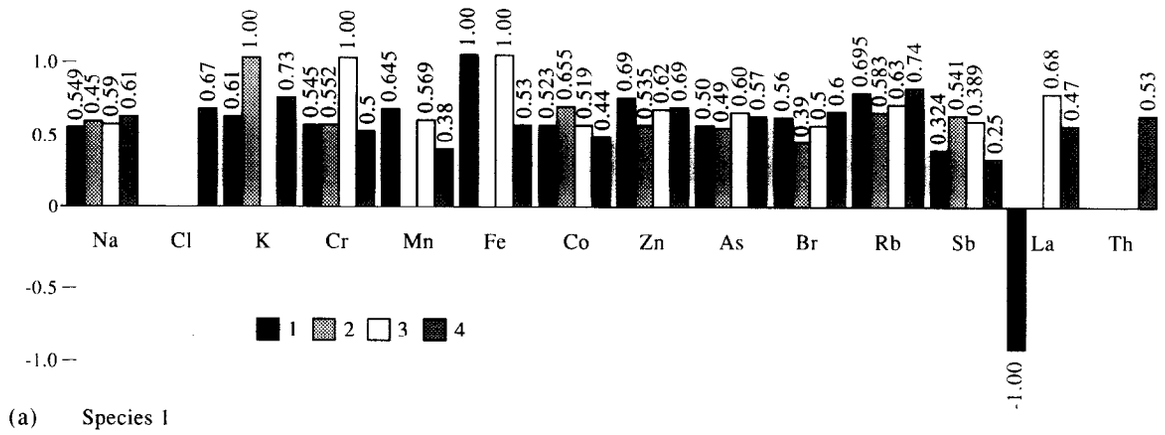


Fig. 1. The distribution of minerals in four species of edible mushrooms.

Ratio of minerals

	1	2	3	4
Na	0.549	0.45	0.59	0.61
Cl	0	0	0	0.67
K	0.61	1.0	0	0.73
Cr	0.545	0.522	1.0	0.50
Mn	0.645	0	0.569	0.38
Fe	1.0	0	1.0	0.53
Co	0.523	0.655	0.519	0.44
Zn	0.69	0.535	0.62	0.69
As	0.50	0.49	0.60	0.57
Br	0.56	0.39	0.50	0.60
Rb	0.695	0.583	0.63	0.74
Sb	0.324	0.541	0.389	0.25
La	-1.0	0	0.68	0.47
Th	0	0	0	0.53



(a) Species 1

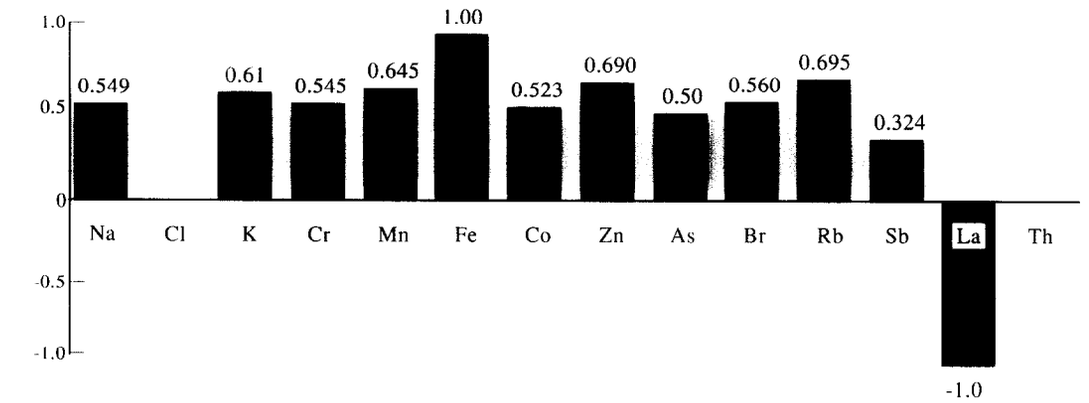


Fig. 2. Ratio of minerals in the pileus to the stalk: Species 1 (a), 2 (b), 3 (c), 4 (d). Averaged distribution of minerals (e).

number is given. Based on the above treatment, the results showed that full 'preferred residence' of the minerals largely occurs in the pileus (K, Fe and Cr) as in species **1**, **2** and **3** and in one case, in the stalk (La) as shown in species **1** (see Fig. 2a–d). Six out of the total of 14 minerals are found to be distributed in both the pileus and stalk. They are Na, As, Rb, Sb, Zn and Co; Th and Cl, although distributed in both the pileus and stalk, are only detected in the species *Termitomyces* sp.

The average distribution ratio of minerals in the pileus to the stalk for all the species studied (Fig. 2e), showed that the mineral's 'preferred residence' is in the pileus, with the exception of Sb.

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Distribution of minerals varied from species to species with an exceptionally high content of Na in species *A. bisporus* and Fe in species *Termitomyces* sp. (see Fig. 3a–d). In all the four species studied, there is an obvious inverse relationship between Na and Rb. Taking species *P. sajor-caju* as an example, Rb is present in high quantity when the Na level is at its minimum. In the absence of Fe, Na domination becomes favourable, with Rb level kept at a minimum. However, it is peculiar that when the Na and Rb levels are comparable, the Fe concentration is high, as observed in species *Termitomyces* sp. It is important to note that each of the species has gone through a different substrate/environment. The uptake of a certain mineral is under the influence of

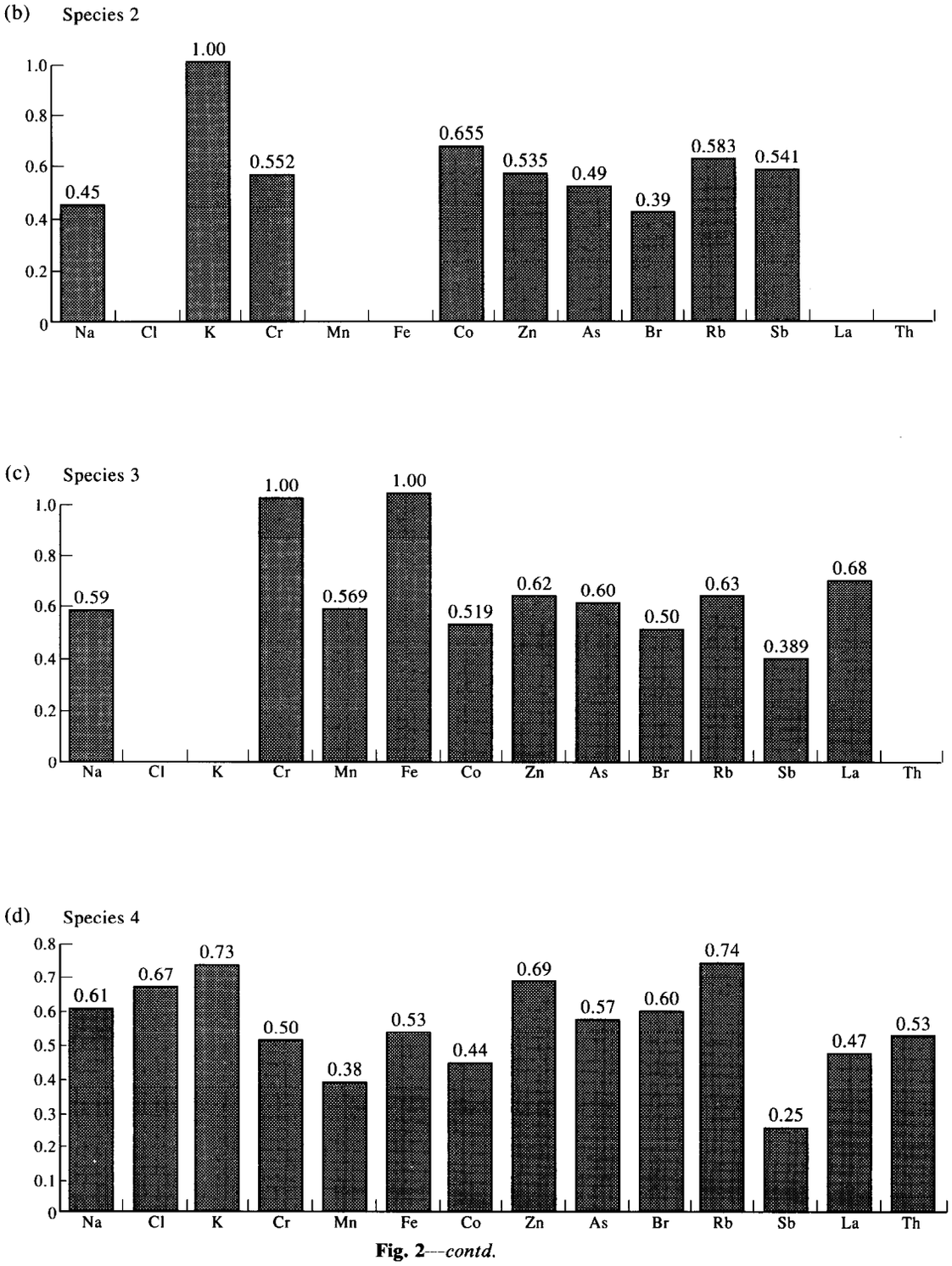

Fig. 2—*contd.*

other minerals, which can either stimulate or antagonize the absorption of that mineral. An excess or otherwise of one or more of the minerals will affect the levels of other minerals.

Mineral characterization in the orders of mushrooms

Overall, the seven species of mushrooms used in this work can be divided into three different orders: *Agaricales, Tremellales* and *Polyporales*. The species marked * in Table 2 are under the order *Agaricales*, *A. auricula* is under the order *Tremellales* and *Ganoderma* spp. under the order *Polyporales*. The distribution of specific elements such as K, Zn, Rb and Th in the three orders are laid out in Table 2.

Table 2 shows that the concentrations of K and Zn are very significant in the order *Agaricales* as compared to the order *Tremellales* and *Polyporales*. The concentration

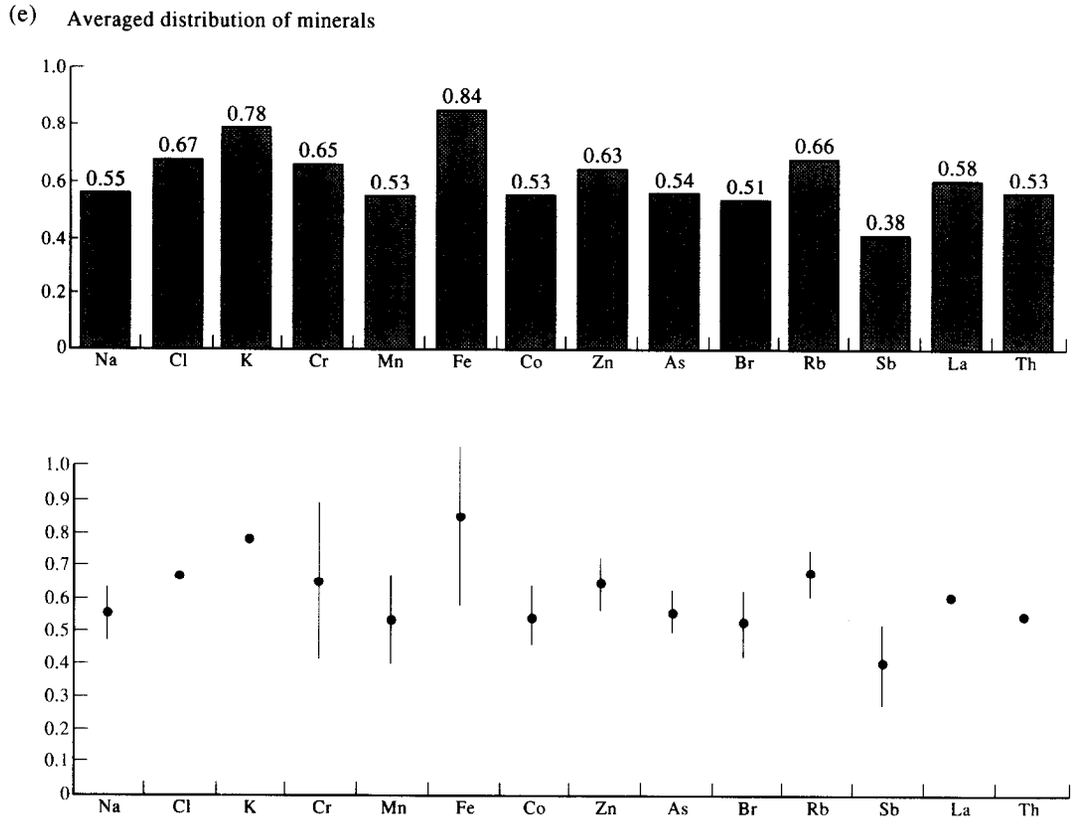

Fig. 2—*contd.*

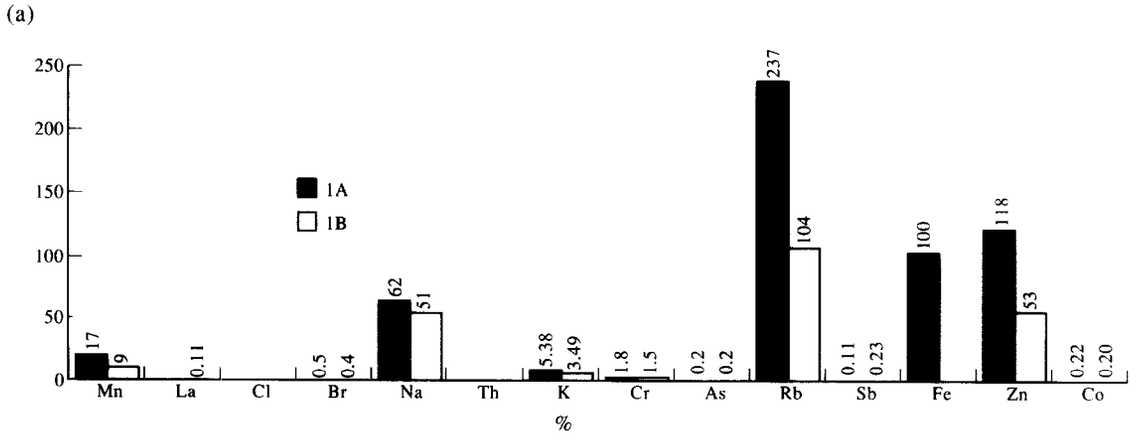

Fig. 3. Distribution of minerals in the pileus and stalk: Species 1 (a), 2 (b), 3 (c), 4 (d).

of Th decreases as follows: *Agaricales* > *Polyparoles* > *Tremellales*. Broadly speaking (with the exception of K, which is a non-transition metal), the concentrations of the metals vary with the atomic weights; the heavier the metal, the lower the concentration in all the three orders. This lends further support to the observation made by earlier workers (Jain *et al.*, 1988) who concluded that the more toxic metals, such as Pb and Cd (in our case, the heavier elements), were translocated into the mushrooms to a smaller extent.

Table 2. The concentrations of elements in the three orders of mushrooms

Elements (atomic weight)	*Agaricales**	*Tremellales* (*A. auricula*)	*Polyporales* (*Ganoderma* spp.)
K (39.1)	1.46–9.10	—	—
Zn (65.4)	150–376	23	22
Rb (85.5)	24–341	22	15
Th (232)	0.51–7.09	0.24	0.37

**P. sajor-caju*; *A. bisporus*; *L. edodes*; *Termitomyces* sp. and *S. commune*.

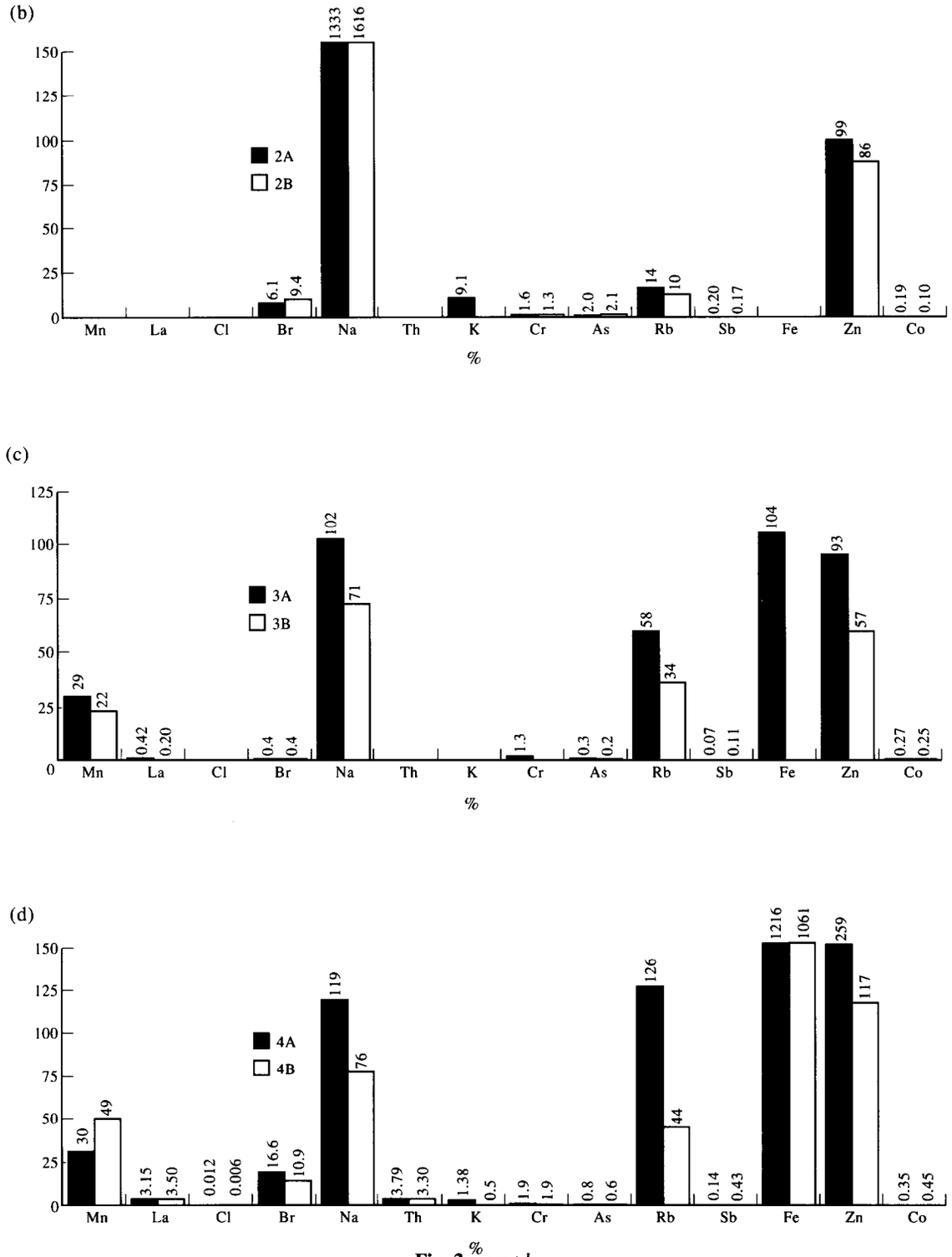

Fig. 3—*contd.*

CONCLUSION

Elemental analysis by the INAA method showed that the mineral contents in the seven species of edible mushrooms varied by species and parts, and that the Na, Fe and Zn contents were many times more abundant then the other minerals detected. Most of the elements showed a 'preferred residence' in the pileus (except for Sb). There is an intricate balance between the elements present in the species studied, particularly between Na, Rb, Fe and Zn.

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