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ON THE ACCUMULATION OF RADIOACTIVE MATERIALS IN MARINE ORGANISMS ALONG THE COAST OF KOREA*

1. Gross Alpha and Beta Activities in Several Edible Marine Algae

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ABSTRACT

In order to clarify the accumulation of radioactive materials in marine organisms of Korea, the present investigation is carried out with 54 samples of edible seaweeds collected from eight sampling sites along the coast of Korea during September, 1973 and April, 1974.

In this paper, ash contents, gross alpha activities and gross beta activities are detected. The ash content is 7.53-15.95% in the species investigated. Among the algal phyla it is about 13.13% in green algae, 12.77% in brown algae, and 10.77% in red algae on an average.

On the other hand, gross alpha activities fluctuate from 180.0 pCi/Kg to 1082.6 pCi/Kg-fresh material experimented, and are 530.72 pCi/Kg on an average. They increase from green to red and brown algae, in turn. The activities in a single species collected at the same season increase from eastern to western and southern coasts of Korea, in turn. Gross beta activities, however, fluctuate from 2.40 nCi/Kg to 22.14 nCi/Kg-fresh material experimented, and 9.03 nCi/Kg on an average. They increase also from green to red and brown algae, in turn. The gross beta activities are specially higher in *Sargassum thunbergii*, 22.14 nCi/Kg. It is expected that this plant could be an indicator to detect the activities in the marine algae along the coast of Korea.

INTRODUCTION

In Asian countries, especially in south-eastern Asia including Korea, Japan and China, etc., numerous marine organisms such as seaweeds, fishes and invertebrates are used for food materials (Chapman, 1950, Fan, 1953, Ueda, 1963). Radioactive isotopes can be accumulated in these organisms when the marine environment in which they live is contaminated with radioactive wastes from various nuclear energy establishment or nuclear powered vessels and fallout from nuclear tests. Therefore, the contamination of marine ecosystem affects directly and more seriously the welfare of these Asian people (Chandler and Widner, 1963, Feldt, 1966).

In Korea peninsula, we have many fishes, seaweed farms and shell-fish breeding beds in inshores. Large quantities of marine products are taken for food materials and some of them are exported. Under the circumstance, the present investigations are carried out in order to clarify the behavior of radioactive materials

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in the marine ecosystem, especially to investigate the contents of radioactive isotopes among seawater, edible seaweeds, and shell-fishes, etc. In this paper, first of all, the gross alpha and beta activities and also the ash contents in common edible seaweed samples collected along the coast of Korea are detected.

MATERIALS AND METHODS

Materials

Marine algae in Korea investigated up to now are more than 400 species, belonging to 180 genera (green algae 65 spp., brown algae 100 spp., and red algae 260 spp.: Kang, 1966). Among them more than 50 species are used for foods especially when they are juvenile (Kang, unpublished). Some of them, such as *Enteromorphas, Capsosiphon, Monostromas,* and *Codiums* of green algae, *Scytosiphon, Hizikia, Undarias,* and *Sargassums* of brown algae, and *Porphyras, Gelidiums, Gracilaria,* and *Gloiopeltis* of red algae are most commonly known edible seaweeds, while the cultivation of *Porphyras* and *Undarias* is one of the important marine industries in Korea.

In the present investigation, about 54 seaweed samples (24 species from 8 sampling sites) were used for the analysis of the levels of gross alpha and beta activities, and also for ash contents. The seaweed materials consist of 6 species of green algae; *Capsosiphon fulvelescens-Enteromorpha clathrata* complex, *Ulva pertusa, Enteromorpha linza, Enteromorpha*-complex (mostly *E. linza* and *E. compressa*), and *Codium fragile,* 14 species of brown algae; *Scytosiphon lomentaria, Myelophycus caespitosus, Ishige okamurai, Undaria pinnatifida, Ecklonia cava, Costaria costata, Laminaria japonica, Kjellmaniella crassifolia, Hizikia fusiforme, Pelvetia wrightii, Sargassum fulvellum, Sargassum confusum,* and *Sargassum horneri,* and 4 species of red algae; *Porphyra tenera, Porphyra yezoensis, Gelidium amansii,* and *Chondrus pinnulatus* (*Porphyras* are mixed generally with a few species, they are represented by a dominant species; *P. tenera* for cultivation group, and *P. yezoensis* for noncultivation group). The seaweed samples were collected during September, 1973 and April, 1974 (mostly from December to April) from Kangnung, Samchuck and Kizang (Pusan) of eastern coast, Zindo, Yeosu and Cheju-island of southern coast, and Kunsan and Anmyundo of western coast of Korea. The sampling dates, sites, and the materials collected are summarized in Table 1 and Figure 1.

Methods

In order to remove the impurities such as soil, seawater and other inorganic materials, the samples must be washed in water for several times before ashing. Ashing temperature is regulated at 400C° with temperature controller.

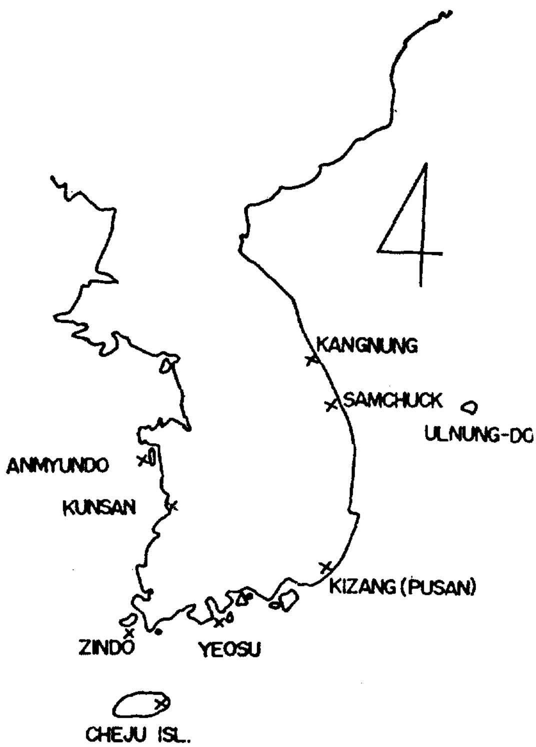

Fig. 1. Sampling sites of the edible seaweeds.

Table 1. The sampling sites, dates and the kinds of edible seaweeds in Korea

	Station	Eastern Coast			Southern Coast			Western Coast	
	Collection Date	Kangnung	Sam-chuk	Ki-zang	Yeosu	Cheju isl	Zindo	Anmy-undo	Kunsan
	Materials	Month/Year	M/Y	M/Y	M/Y	M/Y	M/Y	M/Y	M/Y
Green Algae	*Capsosiphon fulvelescens-Enteromorpha clathrata*			3/74	3/74		1/74	1/74	12/73, 3/74
	Enteromorpha-complex								12/73, 3/74
	Enteromorpha linza			3/74	3/74				
	Ulva pertusa			3/74	3/74	4/74			
	Codium fragile							3/74	12/73
Brown Algae	*Scytosiphon lomentaria*	3/74	3/74		3/74	4/74			
	Myelophycus caespitosus					4/74			
	Ishige okamurai					4/74			
	Undaria pinnatifida	12/73, 3/74		3/74		4/74			12/73
	Ecklonia cava					4/74			
	Costaria costata	3/74	3/74						
	Laminaria japonica				3/74		3/74		
	Kjellmaniella crassifolia	9/73							
	Hizikia fusiforme				3/74	4/74			
	Pelvetia wrightii								12/73, 3/74
	Sargassum thunbergii	3/74		3/74	3/74	4/74			3/74
	Sargassum fulvellum				3/74				
	Sargassum confusum					4/74			
	Sargassum horneri				3/74			3/74	
Red Algae	*Porphyra tenera*				3/74			1/74	12/73, 3/74
	Porphyra yezoensis	3/74							3/74
	Gelidium amansii					4/74			
	Chondrus pinnulatus	3/74							
	Enteromorpha-Porphyra complex							1/74	
	Total	8	2	5	10	10	2	5	12

After ashing, grinding and blending, a suitable aliquot of the ash is taken for analysis.

On the other hand, for gross alpha and beta activities, an aliquot of ash sample is transferred to the tared stainless steel planchet and weighed for counting. The mounted sample is counted in a low background beta counter, LOW BETA II, Beckman. The background count rates of the counting system are less than 1 count per minute at 1 inch planchet for gross alpha and beta activities, respectively (Suschny, 1967, Harley, 1972, Yang 1973). The detection efficiency of gross alpha counting using radium-226 standard source is 50%, and of gross beta counting using thallium-204 standard solution is about 45%.

The abbreviations used in this paper are as follows:

Kangnung : Ka	Sept. 1973 : 9
Samchuck : S	Dec. 1973 : 12
Kizang : Ki	Jan. 1974 : 1
Yeosu : Y	Mar. 1974 : 3
Anmyundo : A	Apr. 1974 : 4
Cheju-isl. : C	
Zindo : Z	
Kunsan : Ku	

RESULTS AND DISCUSSION

Ash content

The ash contents obtained from the present investigation are summarized in Table 2.

As shown in the table, the ash contents in the seaweeds are variable from species to species, fluctuating the mean value from 7.53% of *Gelidium amansii* to 15.95% of *Pelvetia wrightii*, and individually *Capsosiphon-Enteromorpha* complex (Y-3) is the highest, 16.11%. Most of the members show about 11-14% of ash contents. The result accords well with the ones (9.17—16.89%) reported by Lee *et al.* (1970) in some edible brown algae in Korea, whereas it is comparatively low to the ones (10—20%) shown by Ishibashi and Yamamoto (1958) in Japanese seaweeds. On the other hand, in some species, considering the taxonomical relationship of the algae the ash contents explain a similarity among the species in a same genus or order, etc., such as in *Porphyras; P. tenera*, the cultivation group, 12.75%, *P. yezoensis*, no cultivation group, 12.40%, and the members of Laminariales; *Undaria pinnatifida*, 13.33%, *Ecklonia cava*, 12.76%, *Costaria costata*, 13.00%, *Laminaria japonica*, 13.13%, and *Kjellmaniella crassifolia*,

Table 2. Ash percentage of several edible seaweeds in Korea

Materials	Mean	Ash percentage
Green Algae		
Capsosiphon fulvelescens-Enteromorpha clathrata	12.75	10.37(Ku-12), 16.11(Ku-12), 9.49(Ki-3), 15.01(Ku-3)
Enteromorpha-complex	13.11	13.11(Ku-3)
Enteromorpha linza	15.53	15.25(Ki-3), 15.80(Y-3)
Ulva pertusa	13.43	10.67(Ki-3), 13.95(Y-3), 15.68(C-4)
Codium fragile	10.84	8.08(Ku-12), 13.60(A-3)
Brown Algae		
Scytosiphon lomentaria	12.05	11.07(S-3), 11.10(Ka-3), 15.35(Y-3), 10.67(C-4)
Myelophycus caespitosus	10.85	10.85(C-4)
Ishige okamurai	10.89	10.89(C-4)
Undaria pinnatifida	13.33	14.69(Ku-12), 12.19(Ki-3), 12.66(Ka-12), 14.15(Ka-3), 12.95(C-4)
Ecklonia cava	12.76	12.76(C-4)
Costaria costata	13.00	12.80(S-3), 13.20(Ka-3)
Laminaria japonica	13.38	12.31(Y-3), 14.44(Z-3)
Kjellmaniella crassifolia	12.96	12.96(Ka-9)
Hizikia fusiforme	14.88	13.75(Y-3), 16.00(C-4)
Pelvetia wrightii	15.95	15.90(Ku-3), 16.00(Ku-12)
Sargassum thunbergii	14.22	15.45(Ku-3), 15.71(Ki-3), 12.86(Ka-3), 15.77(Y-3), 11.33(C-4)
Sargassum fulvellum	13.67	13.07(Ku-12), 14.20(Ku-3), 13.75(Y-3)
Sargassum confusum	12.04	12.04(C-4)
Sargassum horneri	10.88	10.00(A-3), 11.75(Y-3)
Red Algae		
Porphyra tenera	12.75	12.90(Ku-12), 13.70(Ku-3), 11.08(A-1), 13.31(Y-3)
Porphyra yezoensis	12.40	13.59(Ku-3), 11.20(Ka-3)
Gelidum amansii	7.53	7.53(C-4)
Chondrus pinnulatus	10.41	10.41(Ka-3)
Enteromorpa-Porphyra complex	13.80	13.80(A-1)

12.96%.

Considering the algal phyla, on the other hand, in green algae the ash contents are variable from 10.84% to 15.53%, and 13.13% on an average, while in brown algae they are variable from 10.85% to 15.95% and 12.77% on an average. In red algae, however, they are variable from 7.53% to 12.75%, and 10.77% on an average. As a result, the ash contents among the algal phyla experimented are the highest in green algae, and next in brown algae.

Gross alpha and beta activities

The absorption system of thallophyte including seaweeds is different from that of the land plant; they absorb not only from the holdfast but from all the surfaces of thallus. Therefore, the contents of radioactive substances in the environment influence more directly to the algae inhabited there.

As shown in Table 3 and Figure 2, the gross alpha activities of edible seaweeds in Korea are variable from 183.0 pCi/Kg-fresh material of *Ecklonia cava* to 1082.6 pCi/Kg of *Sargassum horneri*, and 530.72 pCi/Kg on an average. There seems to be no special significance in tendency among the species related phylogenetically. Moreover, the activities are variable even in a single species by the habitat and

Table 3. Gross alpha activities of several edible seaweeds in Korea

Materials	Mean	Activities (pCi/Kg-Fresh)
Green Algae		
Capsosiphon fulvelescens-Enteromorpha clathrata	623.55	712.4(Ku-3), 553.7(Ki-3)
Enteromorpha-complex	657.2	657.2(Ku-3)
Enteromorpha linza	403.6	403.6(Ki-3)
Ulva pertusa	328.5	222.9(Ki-3), 552.2(Y-3), 210.6(C-4)
Codium fragile	368.4	101.7(Ku-12), 635.1(A-3)
Brown Algae		
Scytosiphon lomentaria	680.4	796.1(C-4), 338.6(S-3), 417.5(Ka-3), 1169.5(Y-3)
Myelophycus caespitosus	335.1	335.1(C-4)
Ishige okamurai	616.9	616.9(C-4)
Undaria pinnatifida	576.06	971.5(Ku-12), 253.9(Ki-3), 234.4(Ka-12), 793.7(Ka-3), 625.8(C-4)
Ecklonia cava	183.0	183.0(C-4)
Costaria costata	625.15	727.7(S-3), 522.6(Ka-3)
Laminaria japonica	316.2	316.2(Z-3)
Kjellmaniella crassifolia	580.8	580.8(Ka-9)
Hizikia fusiforme	884.65	546.5(Y-3), 1222.8(C-4)
Pelvetia wrightii	942.40	1069.3(Ku-12), 815-5(Ku-3)
Sargassum thunbergii	482.65	332.9 (Y-3), 428.8(C-4) 702.7(Ki-3), 466.2(Ka-3)
Sargassum fulvellum	502.02	496.0(Ku-12), 508.1(Y-3)
Sargassum confusum	266.9	266.9(C-4)
Sargassum horneri	1082.6	960.2(A-3), 1204.1(Y-3)
Red Algae		
Porphyra tenera	292.8	409.0(Ku-12), 645.1(A-1) 61.5(Ku-3), 55.6(Y-3)
Porphyra yezoensis	614.15	887.5(Ku-3), 340.8(Ka-3)
Gelidium amansii	503.6	503.6(C-4)
Chondrus pinnulatus	686.3	686.3(Ka-3)
Enteromorpha-Porphyra complex	184.5	184.5(A-1)

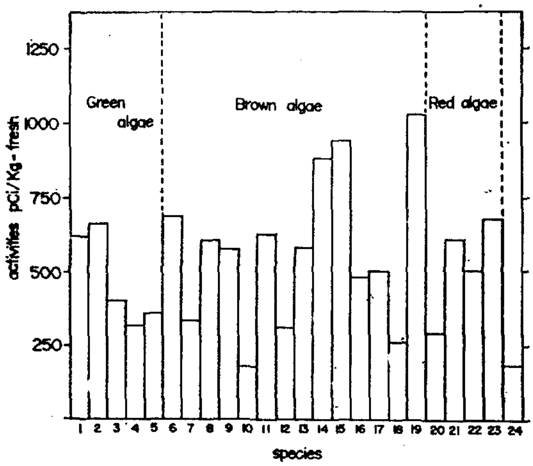

Fig. 2. Gross alpha activities of edible seaweeds in Korea.

1. *Capsosiphon fulvelescens-Enteromorpha clathrata* 2. *Enteromorpha*-complex 3. *Enteromorpha linza* 4. *Ulva pertusa* 5. *Codium fragile* 6. *Scytosiphon lomentaria* 7. *Myelophycus caespitosus* 8. *Ishige okamurai* 9. *Undaria pinnatifida* 10. *Ecklonia cava* 11. *Costaria costata* 12. *Laminaria japonica* 13. *Kjellmaniella crassifolia* 14. *Hizikia fusiforme* 15. *Pelvetia wrightii* 16. *Sargassum thunbergii* 17. *Sargassum fulvellum* 18. *Sargassum confusum* 19. *Sargassum horneri* 20. *Porphyra tenera* 21. *Porphyra yezoensis* 22. *Gelidium amansii* 23. *Chondrus pinnulatus* 24. *Enteromorpah-Porphyra* complex

growing seasons, so that they show closer relationship with the environmental condition than with the metabolic pattern and the physiological factors of the species, etc. The average value of the gross alpha activities is 476.25 pCi/Kg in green algae, 576.75 pCi/Kg in brown algae, and 524.21 pCi/Kg in red algae. It is thought, therefore, the gross alpha activities increase from green to red and brown algae, in turn. On the other hand, the activities in a single species collected along the coast of Korea in a same season show higher value in southern and then western to eastern coasts, in turn; for instance, in *Ulva pertusa* 552.2 (Y-3) and 210 (C-4) v.s. 222.9 (Ki-3), in *Scytosiphon lomentaria* 796.1 (C-4) and 1169.5 (Y-3) v.s. 338.6 (S-3) and 417 (Ka-3), in *Undaria pinnatifida* 971.5 (Ku-12) v.s. 234.1 (Ka-12), in *Hizikia fusiforme* 546.5 (Y-3) v.s. 1222.8 (C-4), in *Sargassum horneri* 960.2 (A-3) v.s. 1204.1 (Y-3) and *Porphyra yezoensis* 887.5 (Ku-3) v.s. 340.8 (Ka-3), etc. *Sargassum thunbergii* and *Porphyra tenera*, however, do not follow this tendency.

The gross beta activities of the edible seaweeds in Korea are also variable among the species experimented from 2.40 nCi/Kg-fresh material of *Ishige okamurai* to 22.14 nCi/Kg of *Sargassum thunbergii* and 9.03 nCi/Kg on an average, as shown in Table 4 and Figure 3. The average value of the gross beta activities is 5.83 nCi/Kg in green algae, 10.81 nCi/Kg in brown algae and 8.02 nCi/Kg in red algae. Therefore, as seen in gross alpha activities, the gross beta activities increase also from green to red and brown algae, in turn. In addition to 11.64 nCi/Kg of *Scytosiphon lomentaria*, 15.90 nCi/Kg of *Hizikia fusiforme*, 22.10 nCi/Kg of *Sargassum thunbergii*, 12.11 nCi/Kg of *Sargassum confusum*, and 14.39 nCi/Kg of *Porphyra yezoensis*, the members of Laminariales show the activities more than 10 nCi/Kg; 10.22 of *Undaria pinnatifida*, 10.81 of *Ecklonia cava*, 12.64 of *Costaria costata*, 13.70 of *Laminaria japonica* and 11.08 of *Kjellmaniella crassifolia*. Especially it is noticeable that the gross beta activities of *Sargassum thunbergii* are about 2-3 times higher than the other edible seaweeds which indicate comparatively high activities. Considering the most commonly occurring feature of the alga along the whole coasts of Korea, it is presumed that *Sargassum thunbergii* would be an indicator plant to detect the gross beta activities of the marine algae along the coast of Korea.

The present analysis of the gross beta activities in edible seaweeds is comparable with the ones reported by Yang and Pak (1973) from some seaweeds at Kori nuclear power plant site (eastern coast) in December 1970 - November 1972, such as laver (=*Porphyra-*

Table 4. Gross beta activities of several edible seaweeds in Korea

Materials	Mean	Activities (nCi/Kg-Fresh)
Green Algae		
Capsosiphon fulvelescens-Enteromorpha clathrata	5.38	2.49(Ku-12), 6.49(Ku-3), 4.30(A-1), 10.49(Ki-3), 3.15(Y-3)
Enteromorpha-complex	5.26	7.95(Ku-12), 2.57(Ku-3)
Enteromorpha linza	5.93	5.93(Y-3)
Ulva pertusa	4.15	3.09(Ki-3), 3.94(Y-3), 5.44(C-4)
Codium fragile	3.44	2.59(Ku-12), 4.29(A-3)
Brown Algae		
Scytosiphon lomentaria	11.64	11.20(S-3), 9.46(Ka-3), 23.72(Y-3), 2.19(C-4)
Myelophycus caespitosus	7.26	7.26(C-4)
Ishige okamurai	2.40	2.40(C-4)
Undaria pinnatifida	10.72	9.83(Ku-12), 11.10(Ki-3), 9.44(Ka-12), 12.25(Ka-3), 10.89(C-4)
Ecklonia cava	10.81	10.81(C-4)
Costaria costata	12.64	11.86(Ka-3), 13.41(S-3)
Laminaria japonica	13.70	10.36(Y-3), 17.03(Z-3)
Kjellmaniella crassifolia	11.08	11.08(Ka-9)
Hizikia fusiforme	15.90	20.81(Y-3), 11.09(C-4)
Pelvetia wrightii	8.40	8.58(Ku-12), 8.22(Ku-3)
Sargassum thunbergii	22.14	21.32 (Ku-3), 37.38(Ki-3), 12.67(Ka-3), 20.96(Y-3), 18.35(C-4)
Sargassum fulvellum	5.74	6.08(Ku-12), 4.64(Ku-3), 6.51(Y-3)
Sargassum confusum	12.11	12.11(C-4)
Sargassum horneri	6.84	5.88(A-3), 7.80(Y-3)
Red Algae		
Porphyra tenera	9.45	6.99(Ku-12), 15.76(Ku-3), 10.25(A-1), 4.79(Y-3)
Porphyra yezoensis	14.39	18.73(Ku-3), 10.04(Ka-3)
Gelidium amansii	4.50	4.50(C-4)
Chondrus pinnulatus	3.74	3.74(Ka-3)
Enteromorpa-Porphyra complex	9.08	9.08(A-1)

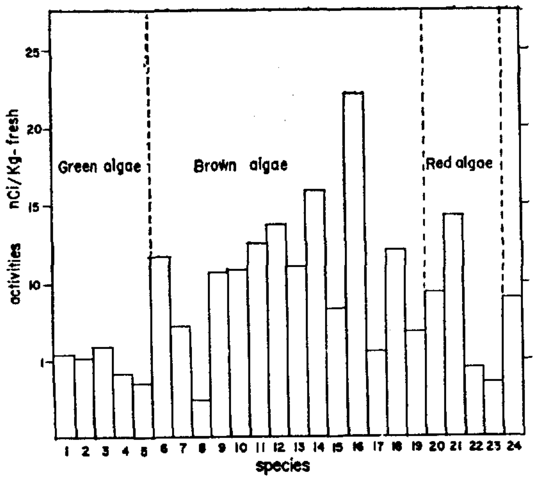

Fig. 3. Gross beta activities of edible seaweeds in Korea.

1. *Capsosiphon fulvelescens-Enteromorpha clathrata*
2. *Enteromorpha*-complex
3. *Enteromorpha linza*
4. *Ulva pertusa*
5. *Codium fragile*
6. *Scytosiphon lomentaria*
7. *Myelophycus caespitosus*
8. *Ishige okamurai*
9. *Undaria pinnatifida*
10. *Ecklonia cava*
11. *Costaria costata*
12. *Laminaria japonica*
13. *Kjellmaniella crassifolia*
14. *Hizikia fusiforme*
15. *Pelvetia wrightii*
16. *Sargassum thunbergii*
17. *Sargassum fulvellum*
18. *Sargassum horneri*
20. *Porphyra tenera*
21. *Porphyra yezoensis*
22. *Gelidium amansii*
23. *Chondrus pinnulatus*
24. *Enteromorpha-Porphyra* complex

complex) 82.66 pCi/g-ash, green laver (=*Enteromorpha linza* and *Enteromorpha*-complex) 37.89 pCi/g-ash, and dulse (=*Undaria pinnatifida*) 122.65 pCi/g-ash (on an average).

CONCLUSION

Ash contents of edible seaweeds in Korea are 7.53-15.95% among the species investigated. The result accords well with the ones reported by Lee *et al.* (1970), and is slightly lower than the ones reported by Ishibashi and Yamamoto (1958) from Japanese seaweeds. Among the algal phyla the ash contents are about 13.13% in green algae, 12.77% in brown algae, and 10.77% in red algae on an average. Therefore, the ash contents are highest in green algae among the three groups.

On the other hand, gross alpha activities of edible seaweeds in Korea fluctuate from 183.0 pCi/Kg to 1082.6 pCi/Kg-fresh materials experimented, and 530.72 pCi/Kg on an average. Among the algal phyla, they are variable from 328.5 pCi/Kg to 657.2 pCi/Kg in green algae, 183.0 pCi/Kg to 1082.6pCi/Kg in brown algae, and 292.8 pCi/Kg to 686.3 pCi/Kg in red algae, respectively, while they are 476.25 pCi/Kg in green, 575.75 pCi/Kg in brown and 524.21 pCi/Kg in red algae on an average. The gross alpha activities in a single species increase from eastern to western and southern coasts of Korea, in turn, compared with the materials collected in a same season.

Gross beta activities are also variable from 2.40 nCi/Kg to 22.14 nCi/Kg-fresh materials experimented, and are 9.03 nCi/Kg on an average. Among the algal phyla, they fluctuate from 3.44 nCi/Kg to 5.93 nCi/Kg in green algae, 2.40 nCi/Kg to 22.14 nCi/Kg in brown algae, and 3.74 nCi/Kg to 14.39 nCi/Kg in red algae, while they are 5.83 nCi/Kg in green, 10.81 nCi/Kg in brown, and 8.02 nCi/Kg in red algae on an average. It is interesting to mention that the gross beta activities are very high in *Sargassum thunbergii*, 22.14 nCi/Kg. It is expected that this plant could be an indicator to detect the gross beta activities of the marine algae along the coast of Korea.

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