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Research Article

Evaluation of Ingestion Exposure to Microplastics Focusing on Korean Pregnant and Lactating Women

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Abstract
Exposure to microplastics is rising as a global issue and specifically a nationwide concern in the Republic of Korea. In this regard, exposure to sensitive population groups, pregnant and lactating women, is essential. In this study, the exposure through ingestion was analyzed considering microplastic levels in potentially risky food items. To do this, I utilized the data provided by the National Institute of Food and Drug Safety Evaluation (NIFDS) of Korea and the Korean National Health and Nutrition Examination Survey (KNHANES) to estimate the daily intake of microplastics, focusing on pregnant and lactating women. Results suggest that pregnant and lactating women have a significantly higher intake of microplastic during their pregnancy and lactating period due to a higher intake of seaweed items such as sea mustard, sea lettuce, and laver, compared to other women. Results are concerning as microplastic exposure during fetal development can cause serious health consequences. Accordingly, to protect sensitive groups including pregnant and lactating women, guidelines or regulations that monitor the concentration of microplastics are needed. Moreover, conducting health effect studies on acute and chronic exposure to microplastics for pregnant and lactating women, along with expanded studies on a wider spectrum of food sources are crucially required.
Keywords: Health Effect, Ingestion Exposure Assessment, Microplastics, Pregnant and Lactating Women.

Introduction

Microplastic, a material that has become an indispensable part of our daily lives, poses a threat to the global ecosystem placing all biota at risk of exposure and potential toxicity. Widespread among humans, microplastics are often found in personal care products, cosmetics, plastic packaging, and many more. Humankinds are already exposed to toxic chemical contaminations in their daily lives [1]. Classified as plastics less than five millimeters in diameter, this characteristic gives them the advantage of easily infiltrating into humans' bodies. They also act as a medium, conveying and transferring toxic and undesirable chemicals [2]. Thus, microplastics can raise important issues for human health, alone or with co-occurring contaminants that attach to them, which may need to be addressed globally on the way toward achieving the third Sustainable Development Goal (SDG3) [3].

Microplastics can be exposed to human bodies through three major routes: ingestion, contact and inhalation [4]. Among these exposure routes, ingestion is more frequent and crucial by letting microplastics or other attached chemicals be consumed and accumulated in one's body. Due to the worsening environmental pollution by microplastics, they are commonly detected in a wide range of foods such as seafood, seaweed, beer, honey, carbonated beverages, and even fruit juices [5]. Microplastics can be accumulated in aquatic organisms such as fish, a common human dietary source, due to the increasing aquaculture activities and the extensive usage of plastic products such as fishing nets and foam buoys [6].

Microplastics can also be exposed through cosmetic products, making women at their fertility age more vulnerable to intake microplastics via both ingestion and contact routes. Accumulation of microplastics in women's bodies would cause biological damage such as weakening the reproductive system [7]. Microplastics absorb chemicals containing endocrine-disrupting chemicals (EDCs), such as bisphenols, phthalates, and dioxins. These contaminants can bring detrimental effects on mammalian endocrine components such as the adrenal, testes, and ovaries [8]. The various EDCs often share a similar structure with specific hormonal receptors in the human body, hence interfering with normal hormone receptors [9].

Therefore, microplastics can induce endocrine disorders, including metabolic disorders, developmental disorders, and even reproductive disorders [2]. Moreover, according to a study conducted by Hwang et al. [10], polystyrene microplastic (PS-MP) accumulation led to decreased ovary size affecting the pregnancy rate, disrupting the embryo, and decreasing embryo production. Results presented by Yang et al. [7] yielded that microplastics can harm the quality and development of oocyte maturation.

Not only is the exposure to microplastics during pregnancy problematic but also microplastic contamination in breastmilk is another concerning aspect that could negatively impact infants [11, 12]. Prior studies suggest that microplastics along with multiple substances, such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and phenols, were detected in human breast milk. The majority of these contaminants are lipophilic indicating the possibility of transfer to the infant through lactation [13]. Early-life infants are particularly more vulnerable and sensitive to such compounds which could damage endocrine and cognitive systems along with reducing IQ and altering behavior [14]. Nevertheless, due to several uncertainties, so far no tolerable daily intake (TDI) has been found for exposure to microplastics [15, 16].

In early 2022, the National Institute of Food and Drug Safety Evaluation (NIFDS) of Korea announced the results of a nationwide study on the concentration of microplastics in some foods that may have potentially high amounts of microplastics [17]. This study, which has been documented by Pham et al. [5], showed an estimation of 16.3 particles for Koreans' weekly ingestion of microplastics based on the Korea National Health and Nutrition Examination Survey (KNHANES) results for the years 2013-2015 [17]. The NIFDS evaluated this intake not to be potentially risky for health considering the whole nation. However, very limited studies considered the potential exposure to microplastics for pregnant and lactating women through their diets.

Accordingly, this research aims to investigate the exposure to microplastics in Koreans, focusing on pregnant and lactating women, by considering their most recent diet pattern for ingesting foods with potentially high amounts of microplastics.

Materials and Methods

Selection of Food Items and Their Associated Concentration of Microplastics

In this study, I used nine food items and the result of microplastic levels in them as presented by NIFDS [17] and documented by Pham et al. [5]. These food items, including carbonated beverages, fruit juice, beer, soy sauce, honey, fish sauce, salt-fermented seafood, and seaweeds, were chosen following the detection of notable levels of microplastics in them. The microplastic concentrations of the food items were measured using the microscope-FT-IR method [5, 19]. The conversion calculation from the particle level of microplastics in food to the mass level was executed assuming a density of 1 mg/mm^3 for a sphere-shaped microplastic particle with 0.1mm diameter [5]. This can be a reasonable assumption since the range of density for different types of microplastics varies from 0.81-1.24 mg/mm^3 [19]. Table 1 presents the concentration of microplastics and their components in the chosen food items.

Food Intake Analysis

The results of the KNHANES, conducted by the Korea Disease Control and Prevention Agency during 2017-2021, were used to estimate the amount of intake for the selected food items in Korea [20]. The KNHANES provides annual surveys which include the investigation of food intake through 24-hour recall face-to-face interviews. These results are widely used by different studies to understand the Korean diet along with the intake of investigating food items [5, 21].

Figure 1 presents the subject selection procedure. KNHANES 2017-2021 includes a total of 38,678 participants. Among them, 33,126 subjects participated in the 24-hour recall interview for the nutrition examination survey. Among them, I considered only adult subjects and derived the daily intake of aimed food items. For each subject, information on age, gender, body weight, pregnancy or lactation status, total daily food intake, and daily intake of nine target food items was derived and analyzed using the KNHANES raw data. Thereafter, the ratio of the sum of the daily intake of nine target food items to the total daily food intake has been calculated. For 5 participants, this ratio exceeded the value of one. Accordingly, I excluded these participants from further investigation. When body weight was not presented, the average body weight at the age of the subject, suggested by the National Institute of Environmental Research (NIER) has been assigned [22]. The socio-demographic information of the subjects is presented in Table 2.

Table 1. Selection of food items and their associated concentration of microplastics [5, 17].

Food items	Total MPs concentration (particle/g) [Mean±SD]	Composition of microplastics (%)				
		Polyethylene (PE)	Polypropylene (PP)	Polystyrene (PS)	Polyethylene terephthalate (PET)	Others
Carbonated beverage	0.003±0.002	11%	53%	<1%	28%	8%
Fruit juice	0.04±0.04					
Beer	0.01±0.09	34%	34%	<1%	<1%	28%
Soy sauce	0.04±0.03	60%	27%	<1%	11%	2%
Honey	0.3±0.2	31%	54%	<1%	9%	6%
Fish sauce	0.9±1.2	61%	24%	11%	2%	2%
Salt-fermented seafood	6.6†±4.6	73%	23%	2%	<1%	2%
Seaweeds	4.5±3.5	51%	44%	<1%	<1%	4%
Table salt (excluding sea salt)	0.5±0.8	14%	66%	<1%	12%	8%

†Average levels of 6.6 particle/g and 5.3 particle/g were reported by NIFDS [17] and Pham et al. [5], respectively. While the difference may not be significant, the higher value is chosen for further analysis.

Table 2. Socio-demographic information of the subjects.

Items		n (%)	Mean±SD (min-max)
Gender	Male	11,643 (43.2%)	-
	Female	15,325 (56.8%)	-
Pregnancy and lactation status (for women)	Pregnant women	103 (0.7%)	-
	Lactating women	109 (0.7%)	-
	Other women	15,113 (98.6%)	-
Age Range	10s	239 (0.9%)	-
	20s	2971 (11.0%)	-
	30s	3743 (13.9%)	-
	40s	4730 (17.5%)	-
	50s	5002 (18.5%)	-
	60s	4948 (18.3%)	-
	70s	3765 (14.0%)	-
	80s	1570 (5.8%)	-
Age		26,968	52.5±17.1 (19-80)
Body weight (kg)		26,968	64.0±12.5 (30.6-164.8)
Daily food intake (g/day)		26,968	1495±780 (21.4-10,862)
Selected foods intake to daily food intake ratio (%)		26,968	4.43±9.93 (0.00-99.6)

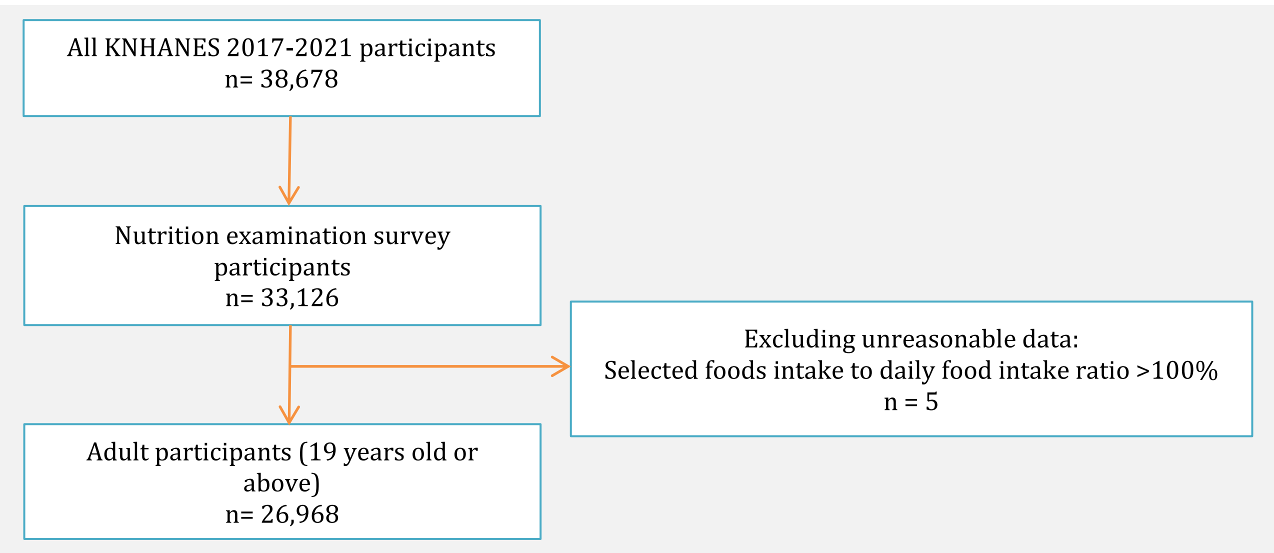

Figure 1. Subject selection procedure.

Analysis of Ingestion Exposure to Microplastics

The estimated daily intake (EDI) for each food item was calculated through Equation 1. The EDI (mg/kg-day) represents the estimated daily intake, C (mg/g-WW food) is the average concentration of microplastics measured in a food item, IR (g-WW food/day) is the average food consumption for each target group, and BW (kg) is the average body weight of the subject in a target group [5, 21].

$$EDI = \frac{C \times IR}{BW} \quad \text{(Eq. 1)}$$

Data Analysis

Differences of parameters between different measuring groups were analyzed using ANOVA and Tukey's range test at the significance level of α = 0.05 using the IBM SPSS Statistics version 26 (IBM Company, Armonk, NY, USA).

Results

Results of Total Microplastics Intake

Considering whole subjects, for each target food item results of daily intake, daily ingestion of microplastics, and the EDI of microplastics are presented in Table 3. The average food intake of whole food items was 85.7 g/day. The average daily intake of food items varied among each food item. Fish sauce had the minimum average intake of 0.27 g/day while beer had the maximum average intake of 51 g/day. The average daily ingestion of microplastics for all food items was 26.7 particles/day (equivalenting to 14µg/day). Carbonated beverages had the minimum daily MP ingestion of 0.01 particles/day (equivalenting to 0.006 µg /day) while seaweeds had the maximum daily MP ingestion of 16.7 particles/day (equivalenting to 8.72 µg/day). The estimated daily intake for all food items was 0.22 µg/kg-bw/day. The minimum EDI was associated with carbonated beverages with a value below 0.001 µg/kg-bw/day while seaweeds had the maximum EDI of 0.14 µg /kg-bw/day.

Table 3. Results of daily food item intake and associated microplastic ingestion.

Food items	Daily intake of food items (g/day) [Mean±SD (min-max)]	Daily ingestion of microplastics [Mean±SD (min-max)]		Estimated daily intake (EDI) of microplastics (µg/kg-bw/day) [Mean±SD (min-max)]
		Unit: particle/day	Unit: µg/day	
Carbonated beverage	4.33±42.5 (0.00-1992)	0.01±0.11 (0.00-5.00)	0.006±0.06 (0.00-3.00)	0.00008±0.00082 (0.00-0.03)
Fruit juice	16.8±78.2 (0.00-1934)	0.62±2.89 (0.00-72.0)	0.33±1.51 (0.00-37.0)	0.005±0.025 (0.00-0.84)
Beer	51.0±235 (0.00-6413)	0.56±2.58 (0.00-71.0)	0.29±1.35 (0.00-37.0)	0.004±0.020 (0.00-0.45)
Soy sauce	6.27±10.1 (0.00-299)	0.23±0.36 (0.00-11.0)	0.12±0.19 (0.00-6.00)	0.002±0.003 (0.00-0.07)
Honey	0.58±4.31 (0.00-152)	0.15±1.08 (0.00-38.0)	0.08±0.56 (0.00-20.0)	0.001±0.009 (0.00-0.30)
Fish sauce	0.27±1.42 (0.00-53.8)	0.25±1.35 (0.00-51.1)	0.13±0.71 (0.00-27.0)	0.002±0.012 (0.00-0.44)
Salt-fermented seafood	1.12±5.85 (0.00-212)	7.38±38.6 (0.00-1399)	3.87±20.2 (0.00-732.6)	0.061±0.313 (0.00-11.9)
Seaweeds	3.70±17.3 (0.00-1075)	16.7±77.8 (0.00-4836)	8.72±40.8 (0.00-2532)	0.140±0.652 (0.00-36.3)
Table salt (excluding sea salt)	1.61±2.70 (0.00-117)	0.82±1.37 (0.00-60.0)	0.43±0.72 (0.00-31.0)	0.007±0.011 (0.00-0.51)
All food items	85.7±252 (0.00- 6460)	26.7±87.5 (0.00-4839)	14.0±45.8 (0.00-2534)	0.223±0.728 (0.00-36.3)

Figure 2a presents the daily intake of food items per day for subjects categorized by gender and age groups. In general, for men, beer displays the highest contribution to the daily food intake at all age ranges. In this study, Korean men had their maximum daily intake during their 30s while they had their minimum daily intake during their 80s. Korean women subjects in this study consumed substantially less amount of food compared to men. Furthermore, unlike men, beer is not the domineering contributing item in Korean women's food diet. Like men subjects, women subjects had their maximum daily intake during their 30s and their minimum daily intake during their 80s. Figure 2b presents the daily particle ingestion of microplastics, dividing the subjects into gender and age groups. Although having the minimum daily food intake, men in their 80s showed the maximum daily ingestion of microplastics, while men in their 20s had the minimum daily ingestion of microplastics. As for women, in general, they relatively had lower microplastic intakes via target food items compared to men. They had their maximum ingestion of microplastics in their 40s while their minimum daily ingestion of microplastics was associated with women in their 10s. Despite gender and age, seaweed was the major contributor to microplastic ingestion among the selected food items. Figure 2c presents the contribution of each food item to the EDI of microplastics based on the subject's age and gender. Results yield that seaweed has the highest contribution for men of all ages. Men at the age of nineteen in this study, display the maximum contribution of seaweed (80.2%), while men in their 20s are associated with the minimum contribution of 49%. Women in their 40s are associated with a maximum contribution of 70.7% for seaweed, while women at the age of 19 are associated with a minimum contribution of 52.8%.

Regardless of gender, average levels of daily intake of food items or daily ingestion of microplastics among subjects with different age ranges were statistically significant ($p<0.001$). However, results of Tukey's range test show that less food ingestion does not necessarily indicate a lower intake of microplastics. For example, Korean men at the age of 80 years old or higher may have significantly a lower intake of the selected food items. However, a higher intake of food items such as seaweed or salt-fermented seafood at this age can make the intake of microplastics comparable with men in the age range of 40 to 70.

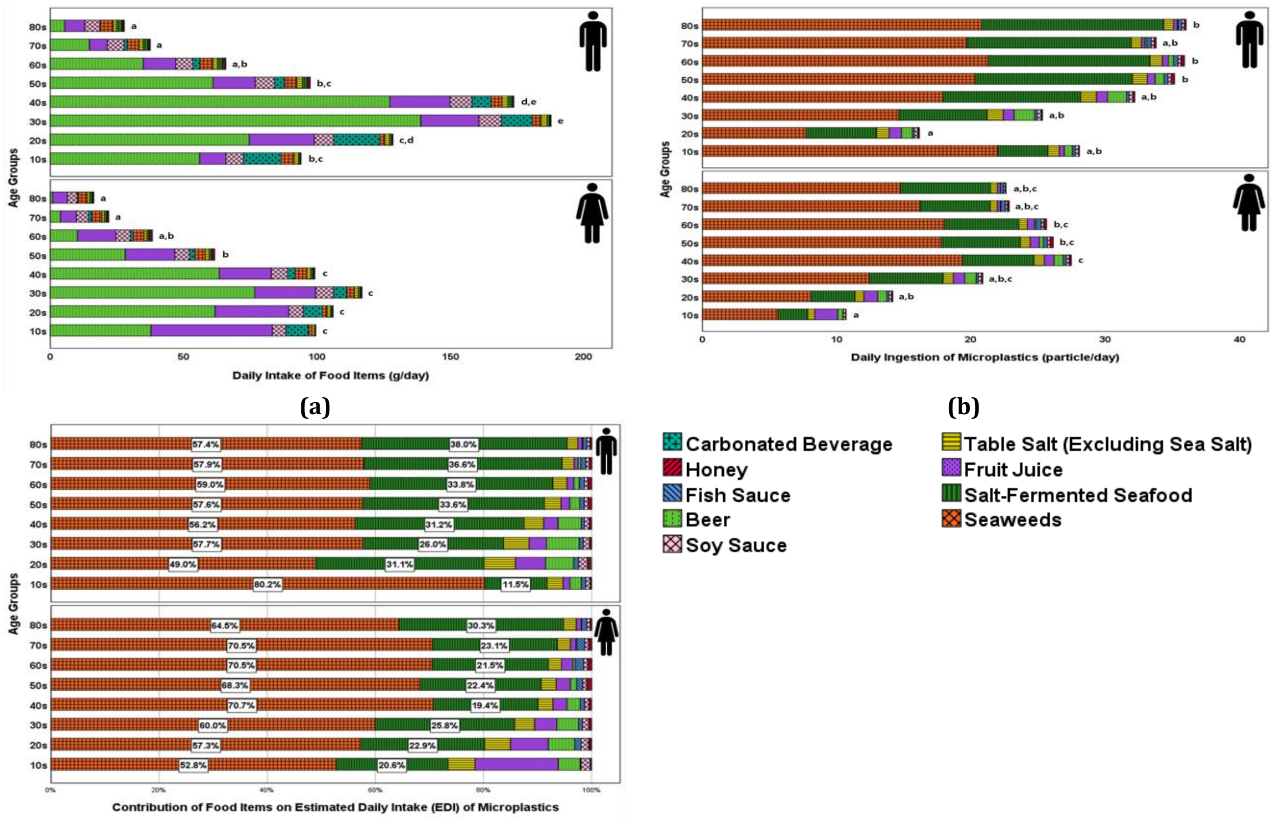

Figure 2. (a) Daily intake of food items, (b) daily ingestion of microplastics, and (c) contribution of food items on EDI of microplastic for different gender and age groups.

Results of Microplastics Intake Estimation for Pregnant and Lactating Women

Table 4 presents the results of daily ingestion and EDI of microplastics for pregnant and lactating women. Bearing in mind that salt-fermented seafood and seaweeds had the highest concentration of microplastics among the target food items, results indicate that the daily ingestion of microplastics from salt-fermented seafood for pregnant women was 4.31 particles per day while this value was 5.96 particles per day for lactating women.

The daily ingestion of microplastics from seaweeds for pregnant and lactating women was 13.9 and 15.4 particles per day, respectively. Overall, the average value of daily ingestion of microplastics was higher for lactating women than for pregnant women. However, when comparing the p95[th] value of salt-fermented seafood for each group, pregnant women had a higher value of 21.5 particles per day compared to lactating women who ingest 11 particles per day.

Table 4. Results of daily ingestion and EDI of microplastics for pregnant and lactating women.

Pregnancy and lactation status	Food items	Daily ingestion of microplastics (particle/day)		Estimated daily intake (EDI) of microplastics (μg/kg-bw/day)	
		Mean±SD (min-max)	p95th	Mean±SD (min-max)	p95th
Pregnant Women	Carbonated beverage	0.01±0.09 (0.00-0.64)	0.00	0.00009±0.00068 (0.00-0.01)	0.00
	Fruit juice	1.84±5.44 (0.00-30.6)	11.5	0.016±0.047 (0.00-0.27)	0.10
	Beer	0.00±0.00 (0.00-0.00)	0	0.00±0.00 (0.00-0.00)	0.00
	Soy sauce	0.22±0.25 (0.00-1.19)	0.77	0.0019±0.0022 (0.00-0.01)	0.01
	Honey	0.07±0.56 (0.00-5.70)	0.08	0.0006±0.0054 (0.00-0.05)	0.0005
	Fish sauce	0.08±0.28 (0.00-1.88)	0.48	0.0007±0.0025 (0.00-0.02)	0.003
	Salt-fermented seafood	4.31±17.7 (0.00-107)	21.5	0.04±0.15 (0.00-1.03)	0.19
	Seaweeds	13.9±48.2 (0.00-398)	42.8	0.12±0.44 (0.00-3.74)	0.39
	Table salt (excluding sea salt)	0.79±0.87 (0.00-4.50)	2.54	0.007±0.008 (0.00-0.04)	0.02
	All food items	21.2±51.4 (0.00-408)	101	0.18±0.46 (0.00-3.84)	0.63
Lactating Women	Carbonated beverage	0.03±0.16 (0.00-1.03)	0.00	0.0003±0.0014 (0.00-0.01)	0.00
	Fruit juice	1.40±4.61 (0.00-30.2)	11.5	0.013±0.042 (0.00-0.27)	0.09
	Beer	0.28±1.27 (0.00-8.88)	2.09	0.002±0.010 (0.00-0.07)	0.02
	Soy sauce	0.30±0.37 (0.00-1.75)	0.98	0.003±0.003 (0.00-0.02)	0.009
	Honey	0.18±1.85 (0.00-19.3)	0.06	0.002±0.016 (0.00-0.17)	0.0005
	Fish sauce	0.15±0.60 (0.00-4.46)	0.58	0.001±0.006 (0.00-0.05)	0.006
	Salt-fermented seafood	5.96±35.9 (0.00-333)	11.0	0.05±0.29 (0.00-2.67)	0.10
	Seaweeds	15.4±43.9 (0.00-397)	62.3	0.14±0.40 (0.00-3.59)	0.72
	Table salt (excluding sea salt)	0.64±0.70 (0.00-3.63)	1.98	0.006 ±0.007 (0.00-0.04)	0.02
	All food items	24.3±57.2 (0.00-397)	114	0.22±0.50 (0.00-3.59)	1.08

Figure 3a presents the daily intake of food items per day for women based on their pregnancy or lactating condition. According to the results, pregnant women had their maximum intake of food from fruit juice. Similarly, lactating women also had their maximum intake of food from fruit juice, even though pregnant women consumed more fruit juice than lactating women. Figure 3b displays the daily ingestion of microplastics for each group. The results suggest that seaweeds were the most contributing food source of microplastic ingestion for all three groups. Compared to pregnant women, lactating women had a higher ingestion of microplastics. Despite the value being less than seaweed, salt-fermented seafood was the other major food item that contributed to the daily ingestion of microplastics. Figure 3c lays out the contribution of food items to the EDI of microplastics for each group. Based on the results, seaweeds contributed the most, by 66.1% and 64.7%, for pregnant and lactating women, respectively. Salt-fermented seafood contributed up to 19.5% for pregnant women and 22.9% for lactating women. Pregnant women consume more seaweed than lactating women while lactating women consume more salt-fermented seafood than pregnant women.

Nevertheless, probably because pregnant and lactating women have small proportions of the sample community in this study, differences in the average levels of daily intake of food items or daily ingestion of microplastics among pregnant, lactating, and other women were not statistically significant (p>0.800).

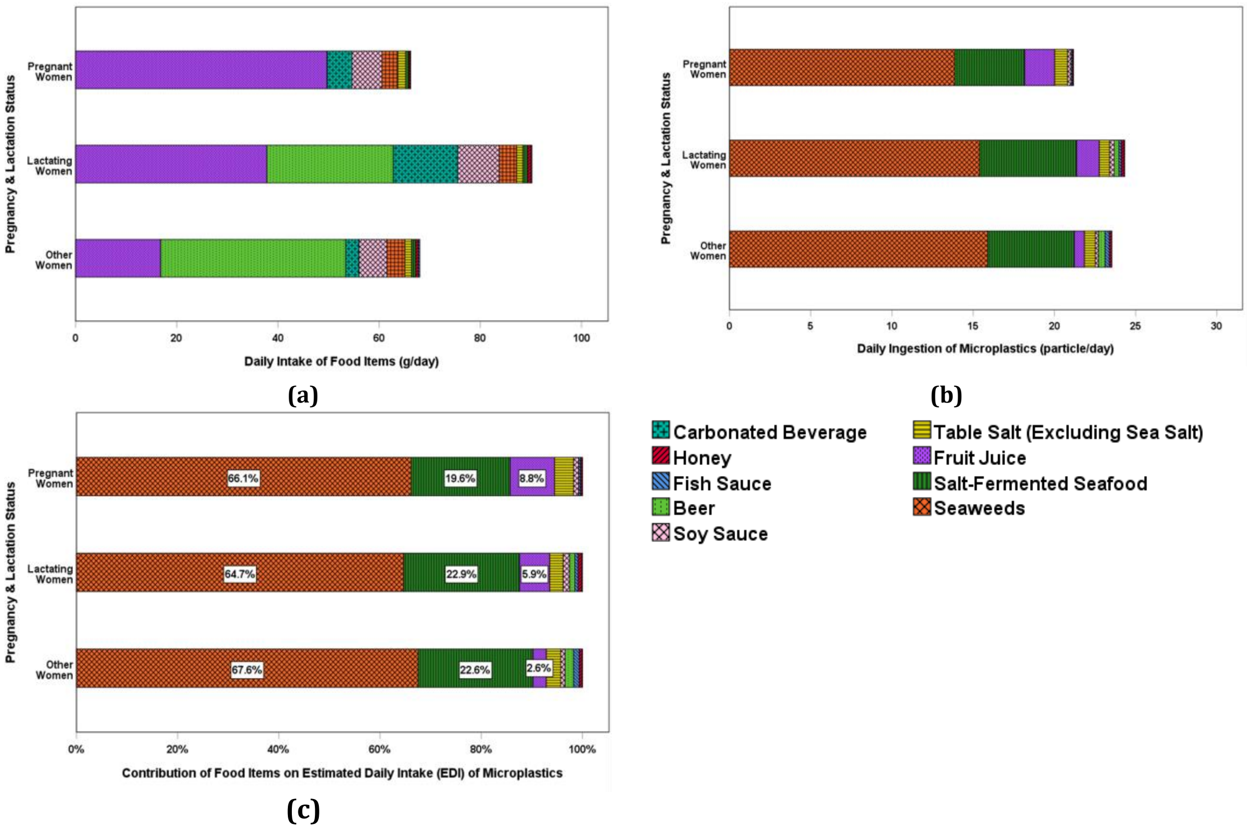

Figure 3. (a) Daily intake of food items, (b) daily ingestion of microplastics, and (c) contribution of food items on EDI of microplastic for different pregnancy and lactation status groups of women.

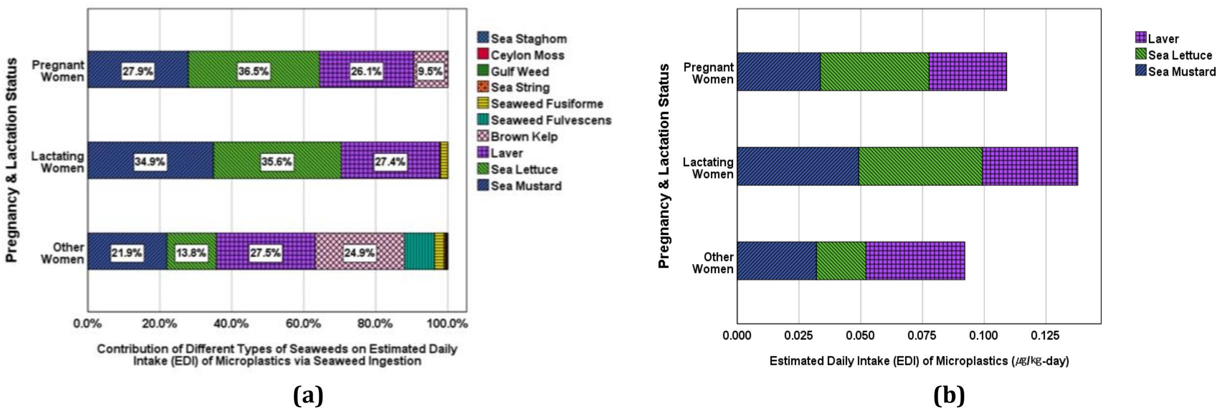

Figure 4. (a) Contribution of different types of seaweeds on EDI of microplastic, (b) EDI of microplastic through top three contributors in seaweeds for different pregnancy and lactation status groups of women (the average concentration of microplastics in all seaweed groups has been considered for each seaweed item).

Discussions

The analysis of daily intake of microplastic in this study was based on the results presented by NIFDS [17] and documented by Pham et al. [5]. The study conducted by Pham et al. [5] is an excellent and pioneering work for examining the existence and concentration of microplastics in different food items in the Republic of Korea. There is a demand for such studies on a higher range of food items, including agronomic products, livestock products, and processed foods and beverages. Considering the average pregnancy period to be 280 days, there will be an average exposure to about 6000 particles, equivalenting to approximately 3.1mg microplastic, or a body burden of 50 μg/kg-bw for a Korean pregnant woman during her pregnancy, which can be transferred to the fetus. Furthermore, WHO [23] recommends a lactating period of 6 months up to two years, which indicates a range of 4300-18,000 particles, equivalenting to approximately 2.3-9.4mg microplastic, or a body burden of 40-161 μg /kg-bw for a Korean lactating woman during her lactating period, which can be transferred to the infant. This may suggest the potential of a notable high exposure to microplastics for Korean women during their pregnancy and lactating period. This long-term accumulation of microplastic particles directly impacts the infant’s health which could lead to serious harm and negative consequences.

Moreover, as presented in Figure 4, pregnant and lactating women have higher EDI of microplastics from seaweed food items of sea mustard, sea lettuce, and laver compared to other women, which may be mainly due to the Korean culture of encouraging more seaweed consumption during pregnancy or lactation period. Seaweed is traditionally known for its nutritional benefits such as containing high amounts of calcium and iodine necessary for breastfeeding and its richness in fiber, protein, vitamins, folic acid, and more [24]. Specifically, sea lettuce, which is one of the two types of seaweed that contributes the most to the overall seaweed consumption of pregnant or lactating women, has multiple nutritional benefits. According to Rolda et al. [25], sea lettuce has sufficient content of macroelements and micronutrients for daily intake. Despite the advantageous nutritional benefits of seaweed, the high contribution of seaweeds in pregnant and lactating women's diets is concerning because seaweeds, along with salt-fermented seafood, have the highest concentration of microplastics among the target food items. Since microplastic exposure directly correlates to the increase in the risk of fetal development, pregnant and lactating women should be informed about the harmful effects of the potential exposure to microplastics through their diet and undergo regular health monitoring, for themselves or their fetus or infants, during pregnancy and lactation period.

Pham et al. [5] suggested washing or soaking seaweed in the water, as a way to reduce the intake of microplastics in seaweed. Such an approach is a simple and useful practical solution to reduce the intake of microplastics from ingesting seaweed significantly. However, secondary pollutants may occur in wastewater treatment plants by introducing the washed-up microplastics into the domestic or natural water cycles, which should be addressed properly.

This study should be considered under several limitations. I obtained the food intake data through the nationwide 24-hour recall investigation executed by the NIFDS. This investigation was not designed to focus on the pregnant and lactating women who were the central target group of this study. Therefore, the number of subjects recorded as pregnant and lactating women was relatively small. Hence, more studies are required to understand and attain data by monitoring the diet habits of pregnant and lactating women during their pregnancy or lactation period, as a part of their regular health check program. Moreover, the target food is indicated as only 3.9% of the total average amount of food in the Korean diet. Therefore, the results might be underestimated as they exclude other potential possibilities of food that could contain a high amount of microplastics. As mentioned earlier, a wider range of food items should be considered for microplastic pollution monitoring in further studies. Moreover, up to now, to the best of the author's knowledge, there is no globally accepted tolerable daily intake (TDI) for plastics has been determined. This is mostly because of the complicated composition of microplastics along with their ability to play the role of a medium for exposure to other toxic materials such as phthalates or alkylphenols [15, 16]. Accordingly, it was not possible to assess and judge the risk of exposure to microplastics via food ingestion.

Despite these limitations, this study can be considered an initial investigation of the microplastic exposure of pregnant or lactating women, showing a notably high intake of microplastics for these sensitive groups. The presented results can support suggestions for creating and running reasonable policies, including guidelines or regulations, that could allow food products to undergo careful monitoring for the concentration of microplastics to protect sensitive groups like pregnant and lactating women can be suggested as a solution. Such regulations or guidelines can be useful to reduce microplastic ingestion by informing people of the microplastic concentration of the food products they are purchasing. To be more specific, a mark for approval that indicates that the product is microplastic-free could enable people to prevent themselves from further microplastic exposure. Currently, there are several regulations established for microplastic use in personal care or cosmetic products across the world [1]. However, fewer ones aim to provide health protection guidelines for microplastics in foods. Thus, domestic or international policies that could promote regular monitoring, measurements, and management of microplastics in specific types of food are needed. Nonetheless, for domestic or international guidelines or regulations to be established, globally accepted standards for analyzing the concentration of microplastics in food items are crucial as the first step [18]. Moreover, health effect studies on acute and chronic exposure to microplastics are required for sensitive groups like pregnant and lactating women and the general population to provide acceptable limits for microplastic exposure based on health risk assessment.

Conclusion

In this study, the daily intake of microplastic through ingestion was analyzed for potentially risky food items using the data provided by the NIFDS [17], Pham et al. [5], and KNHANES [20] focusing on pregnant and lactating women. Results suggest that pregnant and lactating women have a significantly higher intake of microplastic during their pregnancy and lactating period mostly due to higher intake of seaweed compared to other women. The results presented a notably higher intake of microplastic through the ingestion of sea mustard, sea lettuce, and laver in the diet of pregnant and lactating women compared to other women. Results are concerning as the mother's microplastic exposure during fetal development can cause serious health damage to the fetus and infant. Accordingly, to protect pregnant and lactating women, establishing guidelines or regulations that monitor the concentration of microplastics is required. To do this, conducting health effect studies on acute and chronic exposure to microplastics for pregnant and lactating women, along with expanded studies on a wider spectrum of food sources are crucially required.

Declarations

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Author Contribution: The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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Consent to Publish: The author agrees to publish the paper in the International Journal of Recent Innovations in Academic Research.

Data Availability Statement: Publicly available datasets were analyzed in this study.

Data on microplastic concentration in food items are derived from NIFDS [17], which is publicly available here:
https://www.mfds.go.kr/brd/m_99/view.do?seq=46221&srchFr=&srchTo=&srchWord=%ED%9A%8C%EC%88%98&srchTp=0&itm_seq_1=0&itm_seq_2=0&multi_itm_seq=0&company_cd=&company_nm=&page=1.

The data presented from NIFDS [17] has been fully documented by Pham et al. [5], which is cited accordingly.

Data of food intake has been derived from KNHANES 2017-2021 dataset, which is available here: https://knhanes.kdca.go.kr/knhanes/main.do.

The author declares that these datasets are not a part of the results of the presented study and have been utilized as described in the materials and methods section.

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Institutional Review Board Statement: The KNHANES data is publicly accessible and does not include any access to identifiable private information. Therefore, the Institutional Review Board (IRB) approval is not required for the use of the data [20].

Informed Consent Statement: The KNHANES data were collected with prior consent before participating in the survey. The respondents' information was completely anonymized for use in scientific studies and research purposes [20].

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