Turkish J. Eng. Env. Sci.
26 (2002) , 361 – 365.

Metallic Contamination Problem in a Pasta Production Plant

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Received 05.09.2001

Abstract

In this study, we aimed to determine the levels of lead (Pb), cadmium (Cd), arsenic (As) and mercury (Hg) in pasta samples. These metals were determined from samples of wheat, semolina and pasta taken during their processing stages after taking into account the critical production steps that may affect metallic contamination. Determination of heavy metal contents was realized by an atomic absorption spectrophotometer and the stage of sample preparation prior to measurement by using a microwave digestion system in a closed vessel.

Variations in the heavy metal content of the samples taken during the production of pasta were found to be significant from the statistical viewpoint ($p < 0.05$). In general, a decrease was observed in metallic content during semolina production and an increase was observed during the transition from semolina to pasta. The heavy metal contents of samples studied were compared with those reported by other researchers in different countries and similar values were indicated.

Key words: Lead, Cadmium, Arsenic, Mercury, Pasta

Introduction

In line with industrial development, pollution in the environment, and consequently in agricultural raw materials, entail high levels of pollution across the world from the food safety viewpoint. A case of environmental pollution confronted very frequently and threatening food safety is due to heavy metals. As a result of soil, atmosphere, underground and surface water pollution, our foods and beverages are getting contaminated by heavy metals.

Pasta is hard wheat product formed from dough, but not leavened. Pasta occupies a substantial position in human nutrition due to its vitamin, mineral and carbohydrate contents. In this research, levels of lead, cadmium, arsenic and mercury in samples taken in from different production stages were investigated. In addition, determination of variations in the levels of heavy metals during transition from wheat and semolina as raw materials to the end product was another objective of this study.

Materials and Methods

During sampling, duplicate samples of the wheat, the semolina and the pasta were taken from three different stages of the process, and the entire experiment was repeated on five separate occasions.

The grinding process was accomplished in the laboratory using a 2A Model Romer Mill grinding/subsampling mill and the samples were transferred into polyethylene storage containers. The digestion processes were accomplished using a MLS 1200 Mega microwave digestion system (Milestone Sirosole, Italy) and its accessories. The graphite furnace absorption spectrophotometer (AAS) method was used for determining lead and cadmium levels (Jorhem, 1993; Demirözü-Erdinç, 1998; Gawalko

et al., 1997) while the method based on hydride generation was used for measuring the levels of arsenic (Hinners, 1980; Hershey and Keliher, 1989-90; Demirözü-Erdinç, 1998), and the cold vapour generation technique was used to determine mercury levels in the samples (Anonymous, 1987; Baxter and Frech, 1990). The Perkin-Elmer HGA 400 model graphite furnace system and its AS 40 automatic sampler were used in combination with the Perkin-Elmer 1100 model AAS to measure lead and cadmium, and the UNICAM VP 90 hydride system operating in combination with the ATI-UNICAM 929 model AAS were used for arsenic. The Perkin-Elmer MHS-20 mercury/hydride system operating in combination with the Perkin-Elmer 1100 model AAS determined the levels of mercury.

Measurements were made using hollow cathode lamps for lead, cadmium, arsenic and mercury, respectively, and with slit intervals of 0.7, 0.7, 1.0 and 0.7 nm, and at wavelengths of 283.3, 228.8, 193.7 and 253.6 nm for lead, cadmium, arsenic and mercury, respectively. The continuum background correction technique was applied in all measurements, and a D_2-arc lamp was used for this purpose. For determinations of arsenic and mercury, three separate readings were taken on each sample and the mean values of these figures were used to calculate the concentrations. The standard addition method, which minimizes interference effects, was used for the measurement of arsenic and mercury. For lead and cadmium determination, three separate readings were taken from each sample and the means of the values were used to calculate the concentrations. For the determination of arsenic and mercury three solutions were prepared for each sample, and each solution was analysed in duplicate.

The limit of detection for each metal was estimated as 3 times the standard deviation for a 20 run of blanks, and the values for lead, cadmium, arsenic and mercury were found to be 0.21, 0.02, 0.05 and 0.006 ng/g, respectively. The generalised randomised block design system was used during statistical evaluation of the results using the SAS 6.12 program. In addition, the Tukey Multi-Comparison test was applied in order to identify any differences or similarities between products (Hinkelmann and Kempthorne, 1994). In testing processes, an error rate of $\propto = 5\%$ was accepted.

Results and Discussion

No detectable levels of lead, cadmium, arsenic or mercury were observed in the water samples used in the process. The lead, cadmium and arsenic contents for all samples of wheat, semolina and pasta are given in Table 1.

As shown in Table 1, the lead values varied between 26.72 and 52.06 ng/g in wheat, 14.21 and 36.54 ng/g in semolina and 107.08 and 147.58 ng/g in pasta samples. There was a decrease from wheat to semolina and around a five-fold increase from semolina to pasta were observed in all cases. The lead values in the first and second experiments of wheat samples were very close to each other, but were different in other experiments. The reason for this difference might be due to the use of raw materials from different sources in the process. It can be concluded that factors such as the level of lead contamination and the distance from the field to the highway significantly affected the level of lead contamination of the product. Consequently, varying lead values in raw materials as well as in semolina and pasta were expected results ($p < 0.05$).

The embryo, bran and the aleurone layer of wheat are separated during semolina production. These parts are richer in minerals and metals than the endosperm. Sixty-one percent of all minerals in grain are concentrated in the aleurone layer (Hoseney, 1994). As a result of the separation of these parts, an expected decrease was observed from wheat to semolina.

Only semolina and water are used in pasta production. However, kneading, extrusion and heat drying are significant process steps. The temperature was kept around 40°C to provide easy shaping and processing. The pressure was about 90 to 100 bar during extrusion. The surfaces of the extruder in contact with the product played an important role in contamination because of high pressure. The cleaning process of pasta process line is usually performed once or twice a year manually and by mechanical scraping of surfaces. Thus, contamination may be atributed to abrasion on surfaces. Therefore, composition and impurities on the metal section of the production line gain importance. In the statistical evaluation, the variation of lead content in the samples was found to be significant ($p < 0.05$). Also the Tukey Multi-Comparison test revealed that each value of a group was different from that of the others.

Table 1. Lead (Pb), cadmium (Cd) and arsenic (As) contents of all the samples (ng/kg wet weight)

Element	Number of Experiment	Wheat	Semolina	Pasta
Pb	1	44.31 ± 1.21	24.93 ± 1.28	127.04 ± 8.90
	2	44.22 ± 2.28	36.54 ± 2.86	132.17 ± 1.83
	3	49.39 ± 5.07	34.03 ± 4.11	147.58 ± 2.14
	4	26.72 ± 1.33	15.18 ± 1.11	107.08 ± 0.28
	5	52.06 ± 2.76	14.21 ± 0.32	123.05 ± 4.31
	Mean	43.44 ± 9.56	24.98 ± 9.91	127.38 ± 14.26
Cd	1	65.16 ± 1.82	52.08 ± 0.33	53.68 ± 2.21
	2	63.91 ± 2.69	45.16 ± 1.80	42.40 ± 1.30
	3	56.78 ± 4.38	38.77 ± 0.45	41.72 ± 0.65
	4	33.41 ± 2.98	24.49 ± 1.54	25.65 ± 1.85
	5	36.83 ± 0.23	27.34 ± 0.12	27.71 ± 1.38
	Mean	51.22 ± 14.37	37.57 ± 11.04	38.23 ± 10.99
As	1	57.02 ± 0.99	21.87 ± 0.63	40.47 ± 0.69
	2	56.94 ± 0.32	23.87 ± 1.24	42.35 ± 0.06
	3	42.63 ± 0.45	29.00 ± 0.75	40.66 ± 0.28
	4	44.62 ± 1.56	26.64 ± 0.62	40.89 ± 0.06
	5	46.80 ± 0.69	22.19 ± 0.35	48.61 ± 0.74
	Mean	50.00 ± 6.53	24.71 ± 2.94	42.60 ± 3.27

In a study conducted in Canada, variable levels of lead ranging between 30.5 and 36.7 ng/g, and 14.10 and 26.10 ng/g in wheat and cooked pasta collected from different resources were obtained, respectively (Debeca and McKenzie, 1992). Another study in Spain, carried out on different kinds of pasta products including spaghetti and vermicelli, indicates a range 26.5 and 37.1 ng/g (Santos *et al.*, 1993), whereas in Greece the level of 156.3 ng/g was observed in pasta (Tsoumbaris and Tsoukali-Papadopuolou, 1994). When these levels are compared with the results obtained in this study, lead levels in wheat samples were not very different from those obtained in Canada. However, the lead levels in pasta samples (107.08 - 147.58 ng/g) were close to those obtained in Greece.

Cadmium values in the wheat were found to range between 33.41 and 65.16 ng/g, decreasing to 24.49 and 52.08 ng/g in semolina, and to 25.65 and 53.68 ng/g in pasta samples. The variation in the samples during transition from semolina to pasta was not found to be significant while a certain amount of decrease was observed during transition from wheat to semolina. The statistical analysis revealed that the variation between the samples taken at different stages throughout production was significant ($p < 0.05$).

As can be seen from Table 1, the variation in levels of cadmium was not an significant as in the lead values. It is reported that cadmium in plants is equally distributed in all tissues (Merian, 1990). This study also confirmed this situation in wheat kernels. It is known that approximately 20% of raw material is separated as bran and bon-quality flour from the structure during semolina production. It was observed that 70-80% of total cadmium remained in the product during transition from wheat to semolina, but no significant variation was observed during transition from semolina to pasta. This leads to the conclusion that no source ensuring a significant level of cadmium entry into the structure existed during production.

The small variation observed may have originated from the differences that may be created during sampling, and there is also the possibility of the contamination of the air used for drying the product.

Cadmium levels ranging from 33.41 to 65.16 ng/g in wheat samples were much lower from those obtained in Pakistan (250.0 and 390.0 ng/g) but higher than those obtained in Canada (14.66 and 15.68 ng/g) (Ahmad *et al.*, 1994; Debeca and McKenzie, 1992). Cadmium levels ranging from 25.65 to 53.68 ng/g in pasta samples were much lower than those obtained in Greece (62.9 ng/g) and in Finland (79.0 ng/g) (Tsoumbaris and Tsoukali-Papadopoulou, 1994; Tahvonen and Kumpulainen, 1993).

As can be seen from Table 1, arsenic values vary-

ing between 21.87 and 29.00 ng/g in the semolina were the lowest values among the samples during production. A decrease in transition from wheat to semolina and a rise again in transition from semolina to pasta were observed. It is considered that the significant decrease during the transition from wheat to semolina may have originated from the embryo, bran and the aleurone layer separated from the structure, and that the increase during the transition from semolina to pasta may have originated from mechanical erosion and/or metallic fatigue, which may have occurred over the course of time, and from the air used for drying. Variation and differences among samples in arsenic levels were found to be significant ($p < 0.05$). Comparing the values for arsenic obtained from wheat, semolina and pasta samples (42.6-57.0, 21.8-29.0, and 40.4-48.6 ng/g) with the values obtained in a Canadian study (3.0-21.0 ng/g for canned macaroni and 3.9-25.0 ng/g for wheat), it is evident that all the results are higher than the values determined by Canadian researchers (Debeca *et al.*, 1993).

No detectable levels of mercury were found in any of the samples.

It was observed that the plant studied was located near highways on which traffic load was very heavy and was within the industrial zone. These two factors are basic parameters in this increasing contamination trend. The elimination of contamination sources in the production stages, especially the filtration of air used in the drying stage and replacement of old equipment, can decrease the level of lead contamination.

Generally, the locations of other pasta plants in Turkey are far from industrial zones and the traffic density of large cities. For this reason, the lead content of products from these plants may be expected to be lower than those of our research samples.

In the light of the results, the possible contamination sources along the processing line can schematically be represented as in Figure 1.

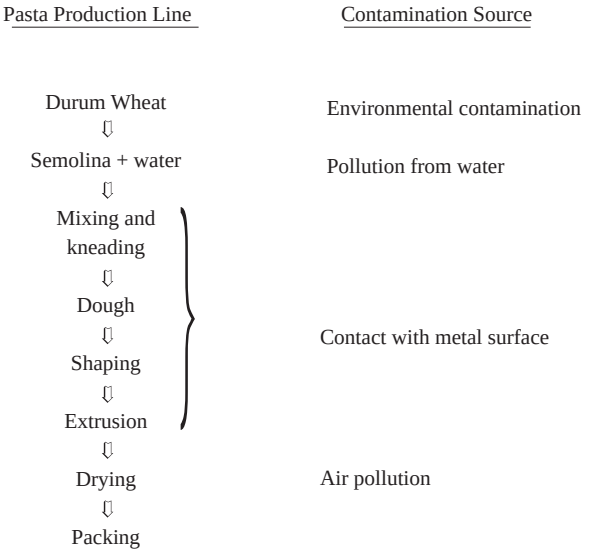

Figure 1. Possible contamination sources during pasta production

Conclusions

In this study, the results related to the pasta production line showed that a decrease in lead, cadmium and arsenic levels took place during the processing of wheat into semolina, but an increase occurred during the transition from semolina to pasta. In general during pasta production, the possible sources of contamination are metal surfaces in contact with the material and those present in air.

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