

Gluten contamination in manufactured gluten-free foods in Turkey

Guler Atasoy, Ozge Kurt Gokhisar & Mahir Turhan

To cite this article: Guler Atasoy, Ozge Kurt Gokhisar & Mahir Turhan (2020) Gluten contamination in manufactured gluten-free foods in Turkey, Food Additives & Contaminants: Part A, 37:3, 363-373, DOI: [10.1080/19440049.2019.1696021](https://doi.org/10.1080/19440049.2019.1696021)

To link to this article: <https://doi.org/10.1080/19440049.2019.1696021>



Published online: 11 Dec 2019.



Submit your article to this journal [↗](#)



Article views: 256



View related articles [↗](#)



View Crossmark data [↗](#)



Citing articles: 5 View citing articles [↗](#)



Gluten contamination in manufactured gluten-free foods in Turkey

Guler Atasoy , Ozge Kurt Gokhisar  and Mahir Turhan 

Department of Food Engineering, University of Mersin, Mersin, Turkey

ABSTRACT

Gluten contamination in manufactured gluten-free foods (mGFFs) is a major health, well-being and economic issue worldwide for both mandatory and voluntary GFF-consumers. Although scarce, a number of surveys have shown that up to 21.5 % of mGFFs in circulation in the market are contaminated with gluten. However, at the present time there is no published work reporting gluten contamination in mGFFs produced in Turkey. In this paper miscellaneous mGFFs produced in Turkey were analysed for gluten concentration (G) to fill this knowledge gap, and to compare the situation in Turkey with worldwide efforts on this issue. A total of 200 mGFFs from 8 product categories (snack, pasta, bread, cookie, cracker, farina, traditional and others), and manufactured using 7 main ingredients (cereal mixture, buckwheat, corn, rice, locust bean, potato, and others) were analysed. A significant portion of mGFFs (17.5 %) were contaminated with gluten and therefore unacceptable as being GFF. The results point to buckwheat as the main cause of this contamination. If buckwheat is excluded, the ratio of unacceptable mGFFs dramatically decreases to 6.3 % and probably to 1.8 %, which are comparable figures to those reported for other countries. Almost all countries are subjected to the same regulations on GFFs, and the problem of gluten contamination could readily be solved to a great extent if pre-market measures are mandated. Enforcing mGFF-producers to screen their raw materials and final products to detect the presence of gluten, and preventing the release of contaminated mGFFs into the market would be a practical measure in favour of all stakeholders involved in GFF-consumption.

ARTICLE HISTORY

Received 30 August 2019
Accepted 11 November 2019

KEYWORDS

Gluten; gluten contamination; gluten-free; food contamination; gluten-linked disorder; coeliac

Introduction

Gluten is a protein fraction found in wheat, rye, and barley, or their crossbred varieties and derivatives (Codex 2015). Uncontaminated oats are generally without problems but are produced in the same facilities as gluten-containing cereals and are subject to cross-contamination. Some individuals cannot tolerate gluten due to having at least one gluten-linked disorder such as coeliac disease, dermatitis herpetiformis, gluten intolerance, gluten ataxia, etc. They have to eliminate gluten from their diets, and mandatorily consume gluten-free foods (GFFs) for a healthy life. GFFs are voluntarily consumed also by some individuals due to reasons other than a gluten-linked disorder, such as health and well-being, weight control, etc. (Miller 2016; Norelle 2016). A food is recognised to be GF if it has a gluten concentration of 20 mg kg⁻¹ at maximum and bears a claim of being GF (Codex 2015).

GFFs could be classified as natural GFFs (nGFFs) and manufactured GFFs (mGFFs). nGFFs do not

contain gluten inherently like fresh fruit and vegetables, milk, etc. Foods manufactured using only GF raw materials do not contain gluten due to their nature, including fruit juice, tomato paste, yoghurt, etc. They are produced for the consumption of ordinary consumers. nGFFs could be released into the market with the claim of GF. In practice, they are not marketed to be GF and not recognised so in the market in the vast majority of cases.

mGFFs are intentionally produced for the consumption of GFF-consumers. They are not produced using gluten-containing raw materials purified from gluten as the GF phrase may imply, analogously to lactose-free milk and caffeine-free coffee, etc. They are produced using GF raw materials to imitate manufactured gluten-containing foods (mGCFs) like bread, pasta, etc. mGFFs are released into the market with the claim of GF and they are recognised so in the market.

The most commonly known gluten-linked disorder is coeliac disease. Its incidence is estimated

as being 1 % for different populations including Turkey (Gursoy et al. 2005; Bai et al. 2013). The incidence of gluten-linked disorders is estimated as high as 13 % excepting coeliac and wheat allergy (Molina-Infante et al. 2015). Sapone et al. (2012) reports that gluten-linked disorders affect almost 10 % of the worldwide population. Though such an assessment for Turkey has not been reported, the same is presumably valid. The rate of voluntary GFF-consumers is estimated to be 25 % in the USA (Mintel 2015) and 8 % in the EU (Kraushaar 2015), and is expected to rise (Mintel 2016). The rate of voluntary GFF-consumers is not yet known for Turkey; however, disclosures encouraging the GFF-consumption have been emerging in the media for a while.

Consumption of GFFs keeps expanding and its issues deserve close attention. Gluten contamination is one of the leading issues in GFFs. The limit of 20 mg kg⁻¹ (20 ppm) gluten is such a low value that a GFF can readily reach it with only a tiny amount of gluten contamination. The gluten contamination issue is critical for firstly mandatory and then voluntary GFF-consumers, and also for other stakeholders involved in the GFF-consumption. Gluten contamination in miscellaneous mGFFs was surveyed for a limited number of markets such as the USA, Brazil, Spain, and Italy (Lee et al. 2014; Sharma et al. 2015; Farage et al. 2016; Mattioni et al. 2016; Bustamante et al. 2017; Verma et al. 2017). Gelinas et al. (2008) made a survey for breakfast cereals in the Canadian market. The highest gluten contamination was reported to be 21.5 % for the Brazilian market (Farage et al. 2016). Such work has not been not yet been conducted for Turkey, and the gluten contamination issue may apply in the Turkish market as well.

A significant quantity of imported mGFFs are available on the Turkish market together with domestic ones. mGFFs to be imported to Turkey must be proved to be GF in advance according to the commerce and custom regulations in effect (Ministry of Food, Agriculture and Livestock of Turkey 2017). Imported mGFFs in the market are in the state of GF in the regulative perspective. Domestic mGFFs are not subject to proof of being GF before release into the market according to the related regulation (TFC 2012) as in other countries (FDA 2013; EC 2014). So, mGFFs produced in Turkey are not controlled for gluten

concentration (G) in the market while imported mGFFs are subject to control. The state of domestic mGFFs in the market in terms of gluten contamination is not known, and the coverage of this work was kept limited to domestic mGFFs. Accordingly, the aim of this work is to analyse for gluten in miscellaneous mGFFs produced in Turkey to evaluate if they are contaminated with gluten, and contribute to efforts for resolving the gluten contamination issue worldwide.

Materials and methods

Preparation for the analysis

Miscellaneous mGFFs (bearing the claim of GF on their packages) produced in Turkey were collected nationwide from supermarket chains and internet venues operating in the Turkish market within the years 2016–2018. Sample preparation and gluten analysis were performed in a Gluten-Free Laboratory in the Department and every possible precaution was taken to prevent cross-contamination of samples with gluten. The outer and inner surfaces of sample packaging were cleaned with an ethanol solution (40 %) to eliminate possible former gluten contamination on them and cross-contamination of the samples during sample preparation.

Sample preparation and the analysis

Collected mGFFs (200) were analysed in triplicate for gluten concentration (G). mGFFs having a mean G > 20 mg kg⁻¹ were denoted to be contaminated with gluten. Gluten was determined using R5 antibody-based R-7001 Ridascreen Gliadin Sandwich ELISA test kit and R-7006 Cocktail solution (R-Biopharm AG, Darmstadt, Germany) for the extraction. The Guidelines from the test kit Company for sample preparation and the analysis were followed exactly as described in detail by Verma et al. (2017). The limit of detection and the range of quantification were reported to be 3 mg kg⁻¹ and 5–80 mg kg⁻¹ gluten, respectively by the test kit provider. Quantification was conducted using a microplate reader (Thermo Fisher Scientific, Multiskan Go Microplate reader, Waltham, Massachusetts, USA) at 450 nm. The gluten content of mGFFs was calculated from

a calibration curve using software (Ridasoft Win, R-Biopharm AG, Darmstadt, Germany). The calibration curve was constructed using standard gliadin solutions (0, 5, 10, 20, 40, and 80 ng g⁻¹ (ppb)) supplied with the test kit. A new calibration curve was prepared for the analysis of every 10 mGFFs.

Testing performance of the analysis

FAPAS® QC Material cake mix (T27160BQC, 20 g) was used to assess the performance of the analysis. The gluten content of the test material was assigned by FAPAS® to be 35.3 mg kg⁻¹ with a Z-score range of 17.7–53.0 mg kg⁻¹ from its data sheet. The gluten content of the cake mix was found to be 34.7 mg kg⁻¹ with a range of 18.5–51.0 mg kg⁻¹ by performing 15 analyses during the time period of the survey. The consistency between the assigned and measured results showed the reliability of the analysis performed.

Results

Codex (2015) indicates that a food intended to be GF must not exceed a maximum gluten concentration (G) of 20 mg kg⁻¹. Thus, if it has a gluten content ≤ 20 mg kg⁻¹, it is recognised to be GF and acceptable; if it has a gluten content > 20 mg kg⁻¹, it is contaminated with gluten and unacceptable. The maximum limit of 20 mg kg⁻¹ is actually on the high side. The existence of gluten in a GFF should not be tolerated, it could be quite risky especially for the health and well-being of mandatory GFF-consumers. The severity of symptoms varies depending on the amount of gluten digested (Catassi et al. 2007). The lowest detectable and quantifiable amounts of gluten in foods are 3 mg kg⁻¹ and 5 mg kg⁻¹, respectively for contemporary routine tests (Koehler et al. 2013; R-Biopharm 2019). An unquantifiable G (< 5 mg kg⁻¹) does not indicate the complete absence of gluten, and any quantifiable gluten (5 ≤ G ≤ 20 mg kg⁻¹) in a food is a sign of gluten presence and therefore contamination. The upper limit of 5 mg kg⁻¹ to replace the current limit of 20 mg kg⁻¹ in the Codex (2015) should be debated by Stakeholders. Considering the capacity of current tests and the current regulatory limit of 20 mg

kg⁻¹, GFFs may be classified in critical gluten content intervals. It may be “acceptable” for gluten content < 5 mg kg⁻¹, “risky” for gluten content 5–20 mg kg⁻¹, and “unacceptable” for gluten content > 20 mg kg⁻¹. The limit of 5 mg kg⁻¹ would be provisional until a lower gluten content could reliably be detected by valid routine tests. Though the limit of 20 mg kg⁻¹ is generally in effect worldwide, the related regulation in Australia and New Zealand (Australia New Zealand Food Standards Code 2014) adopts “the minimum detectable gluten” as the maximum allowable gluten limit in GFFs which is in line with the above suggestion.

mGFFs available in the Turkish market were collected from nine product categories e.g. snack, pasta, bread, cookie, cracker, farina, breakfast cereal, traditional and others’ in a former work on GFF issues in Turkey (Atasoy et al. 2017). No domestic mGFF in the breakfast cereal category is manufactured currently in Turkey. Hence, collected mGFFs were provided under the other eight categories in this work. A total of 200 mGFFs collected comprised of 13 snacks, 57 pastas, 13 breads, 15 cookies, 6 crackers, 56 farinas, 33 traditional products, and 7 others (Figure 1). The main ingredients of mGFFs were declared on their packages by the manufacturers as cereal mixture, buckwheat, corn, rice, locust, others and potato. Accordingly, mGFFs were grouped under the main ingredient used in their recipes, too. Their distribution was 86 in cereal mixture, 42 in buckwheat, 38 in corn, 23 in rice, 6 in locust, 4 in others, and 1 in potato groups (Figure 2).

The distribution of mGFFs is provided in Figure 1 for the product categories in the critical gluten intervals suggested above. mGFFs with a gluten content < 5 mg kg⁻¹ totalling 143 were determined in all 8 product categories. Only 3 categories, all mGFFs (15 in cookie, 6 in cracker and 7 in others, 28 in total) had a gluten content < 5 mg kg⁻¹. The remaining 115 mGFFs with a gluten content < 5 mg kg⁻¹ fell within the other 5 categories (8 in snack, 40 in pasta, 12 in bread, 37 in farina, and 18 in traditional). mGFFs having a gluten content of 5–20 mg kg⁻¹ were detected in 22 foods in 5 categories, e.g. 1 in snack, 7 in pasta, 1 in bread, 11 in farina and 2 in traditional. The number of

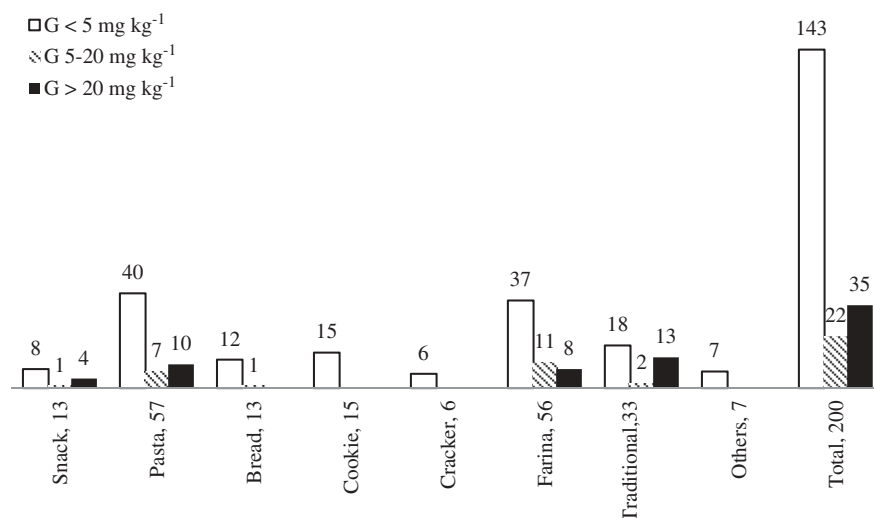


Figure 1. Distribution of mGFFs according to the product categories and the critical gluten concentration (G). Numerals on the abscissa are for the number of mGFFs in the denoted product category and numerals on the bars are for the number of mGFFs in the denoted G.

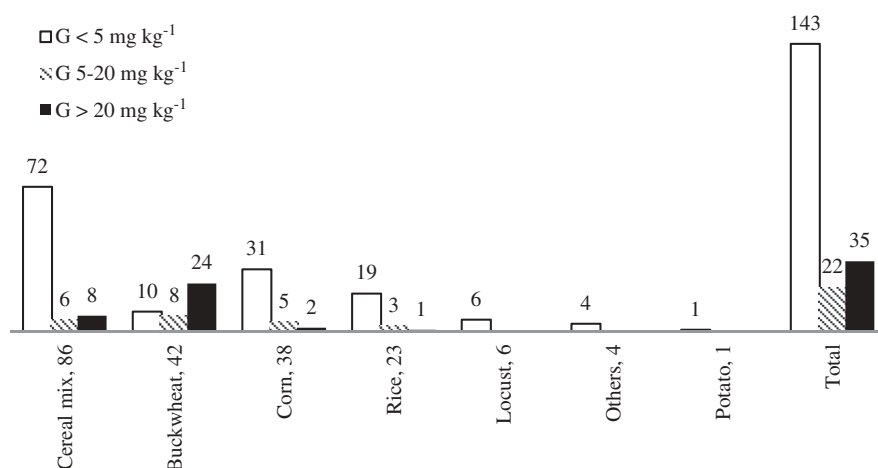


Figure 2. Distribution of mGFFs according to the main ingredient groups and the critical gluten concentration (G). Numerals on the abscissa are for the number of mGFFs in the denoted main ingredient group and numerals on the bars are for the number of mGFFs in the denoted G.

mGFFs with a gluten content $> 20 \text{ mg kg}^{-1}$ was 35 in 4 categories: 4 in snack, 10 in pasta, 8 in farina, and 13 in traditional products.

Distribution of mGFFs is provided in Figure 2 for the main ingredient groups in the suggested critical gluten content intervals. mGFFs with a gluten content $< 5 \text{ mg kg}^{-1}$ (143) were found in all 7 main ingredient groups. In 3 groups only, all mGFFs (6 in locust, 4 in others and 1 in potato, 11 in total), had a gluten content $< 5 \text{ mg kg}^{-1}$. The remaining mGFFs with a gluten content $< 5 \text{ mg kg}^{-1}$ (132) were in the other 4 ingredient groups (72 in cereal mixture, 10 in buckwheat, 31 in corn and 19 in rice). The number of

mGFFs with a gluten content $5-20 \text{ mg kg}^{-1}$ was 22 in 4 ingredient groups (6 in cereal mixture, 8 in buckwheat, 5 in corn, and 3 in rice). mGFFs with a gluten content $> 20 \text{ mg kg}^{-1}$ (35) were found in 4 groups (8 in cereal mixture, 24 in buckwheat, 2 in corn and 1 in rice).

Discussion

Evaluation in the total

mGFFs collected were evaluated for gluten concentration according to the current criterion of

Table 1. Gluten concentration (G) of miscellaneous mGFFs according to countries (mg kg^{-1}).**Num:** Number of mGFFs; **Ratt:** Ratio of mGFFs in the total (%).

Country References	Method of Gluten Analysis	Total	G < 5 Num Ratt	G 5–20 Num Ratt	G > 20 Num Ratt
Turkey Atasoy et al. (This work)	RIDASCREEN® Gliadin R5 Sandwich ELISA	200	143 71.5	22 11	35 17.5
Spain Bustamante et al. (2017)	R5 antibody Transia Plate Gluten, INGEZIM Gluten, Ridascreen Gliadin R5 Sandwich ELISA	3141	2770 88.2	183 5.8	188 6.0
Italy Verma et al. (2017)	Ridascreen Gliadin R5 Sandwich ELISA	93	NAv* NAv	NAv NAv	2 2.2
Brazil Farage et al. (2016)	Ridascreen Gliadin R5 Sandwich ELISA	130	NAv NAv	NAv NAv	28 21.5
Brazil Mattioni et al. (2016)	R5 antibody Transia Plate Gluten	437	NAv NAv	NAv NAv	NAv 11
USA Sharma et al. (2015)	Morinaga wheat protein sandwich ELISA, Ridascreen Gliadin R5 Sandwich ELISA	275	265 96.4	NAv NAv	3 1.1
USA Lee et al. (2014)	Ridascreen Gliadin R5 Sandwich ELISA	78	NAv NAv	NAv NAv	16 20.5
Canada Gelinis et al. (2008)**	Ridascreen Gliadin R5 Sandwich ELISA	77	NAv NAv	NAv NAv	7 10

*NAv: Not available.

**Breakfast category.

20 mg kg^{-1} , and 82.5 % and 17.5 % had gluten contents of $\leq 20 \text{ mg kg}^{-1}$ and $> 20 \text{ mg kg}^{-1}$, respectively (Tables 1–3). A significant portion of mGFFs (82.5 %) were acceptable, and the remaining (17.5 %) were unacceptable according to the Codex (2015). The figure of 17.5 % sits between unacceptable figures of 1.1 % and 21.5 % reported for other markets (Table 1). The unacceptable ratio of 17.5 % may be assumed reasonable based on the support of the acceptable figure 82.5 % from this work and the high unacceptable figures from other publications (Table 1). Such a quantitative and comparative approach is misleading and not descriptive, and does not comply with the underlying meaning and importance of the food contamination issue. In accordance with the sensitivity of the issue and the understanding of no-tolerance, the ratios detected in this work are not acceptable, e.g. the proportion for the acceptable mGFFs (82.5 %) is too low and the proportion for the unacceptable mGFFs (17.5 %) is too high. The gluten contamination in the high

category shows the severity of the issue in the market.

Evaluation in the product categories

Distribution of mGFFs is provided in Table 2 for the product categories in the critical gluten content intervals, and also for certain gluten content intervals above 20 mg kg^{-1} to present the level of the contamination in the categories. It was only in 4 categories that all mGFFs (13 in bread, 15 in cookie, 6 in cracker and 7 in others, 41 in total) had a gluten content $\leq 20 \text{ mg kg}^{-1}$ forming 20.5 % of total mGFFs. The remaining 4 categories (snack, pasta, farina, and traditional) had mGFFs both with a gluten content $\leq 20 \text{ mg kg}^{-1}$ and gluten content $> 20 \text{ mg kg}^{-1}$. Unacceptable mGFFs come from 50 % of product categories. The number of mGFFs with a gluten content $\leq 20 \text{ mg kg}^{-1}$ in these categories was 124 (9 in snack, 47 in pasta, 48 in farina, and 20 in traditional) forming 62.0 % of the total. All 35 mGFFs with

Table 2. Gluten concentration (G) of miscellaneous mGFFs according to the product categories (mg kg^{-1}). **Num:** Number of mGFFs; **Ratt:** Ratio of mGFFs in the total 200 (%), **Ratc:** Ratio of mGFFs in the product category (%).

Product category	Num Ratt	G < 20		G > 20		
		Num Ratt Ratc		Num Ratt Ratc		
		G < 5	G 5-20	G 20-40	G 40-80	G > 80
Snack	13	8	1	2	–	2
	6.5	4.0	0.5	1.0	–	1.0
		61.5	7.7	15.4	–	15.4
Pasta	57	40	7	5	1	4
	28.5	20.0	3.5	2.5	0.5	2.0
		70.2	12.3	8.8	1.7	7.0
Bread	13	12	1	–	–	–
	6.5	6.0	0.5	–	–	–
		92.3	7.7	–	–	–
Cookie	15	15	–	–	–	–
	7.5	7.5	–	–	–	–
		100	–	–	–	–
Cracker	6	6	–	–	–	–
	3.0	3.0	–	–	–	–
		100	–	–	–	–
Farina	56	37	11	3	1	4
	28.0	18.5	5.5	1.5	0.5	2.0
		66.1	19.6	5.4	1.8	7.1
Traditional	33	18	2	5	3	5
	16.5	9.0	1.0	2.5	1.5	2.5
		54.5	6.1	15.1	9.2	15.1
Others	7	7	–	–	–	–
	3.5	3.5	–	–	–	–
		100	–	–	–	–
Total		143	22	15	5	15
		71.5	11.0	7.5	2.5	7.5
		100	100	100	100	100
	200	165		35		
	100	82.5		17.5		

gluten content $> 20 \text{ mg kg}^{-1}$ in these categories accounted for the unacceptable figure of 17.5 %. The ratio of unacceptable mGFFs was 30.8 % in the snack category, 17.5 % in the pasta category, 14.3 % in the farina category and 39.4 % in the traditional category. The ratio of unacceptable mGFFs in some of these categories is considerably higher than 17.5 %. Any mGFF from any product category was supposed to have a gluten content $\leq 20 \text{ mg kg}^{-1}$ for consumption with peace of mind.

Average GFF-consumers have a focused-shopping attitude, e.g. they consume mGFFs mostly from certain product categories. The highest share of the pasta category (28.5 %), the farina category (28.0 %) and the traditional food category (16.5 %) in total mGFFs collected (Table 2) is a reasonable indicator for the response of the market to the high demand for mGFFs in these categories. The aggregate share of mGFFs in these categories is 73.0 % of the total. GF-pasta (mGFF) is the best imitation of

ordinary pasta (mGCF), farina is the best customised and cheapest way of making various home-made mGFFs, and traditional food is the indispensable taste of the Turkish culture. For example, the probability of consuming mGFF contaminated with gluten is between 14.3 % and 39.4 % for a consumer who is a dedicated purchaser of mGFFs from these categories (Table 2). For such mandatory GFF-consumers, the symptoms would be long-lasting, and never be linked to gluten ingestion since they supposedly adhere to a real GF-diet. This absolutely compromises the health of mandatory GFF-consumers, and overcharges both mandatory and voluntary GFF-consumers since mGFFs are much globally more expensive than mGCFs, including Turkey (Lee et al. 2007; Lambert and Ficken 2016; Panagiotou and Kontogianni 2017; Atasoy et al. 2017). The probability of consuming an mGFF contaminated with gluten from certain product categories is apparently most probably higher than 17.5 % and the issue becomes more severe than is obviously apparent.

Evaluation in the main ingredient groups

The distribution of mGFFs is provided in Table 3 for the main ingredient groups in the critical gluten content intervals, and also for certain gluten content intervals above 20 mg kg^{-1} to present the level of the contamination in the groups. All mGFFs in only 3 of 7 main ingredient groups (6 in locust, 4 in others and 1 in potato, 11 in total) had a gluten content $\leq 20 \text{ mg kg}^{-1}$. The aggregate ratio of 11 mGFFs in these groups forming 43 % of the ingredient groups disproportionately constitute a small portion (5.5 %) of total mGFFs. mGFFs with a gluten content $> 20 \text{ mg kg}^{-1}$ were all from the remaining 4 of 7 groups (8 in cereal mixture, 24 in buckwheat, 2 in corn and 1 in rice, 35 in total). These groups represent 57 % of main ingredient groups and are responsible for all unacceptable mGFFs. The aggregate ratio of all 189 mGFFs in these groups disproportionately constitutes a very high portion (94.5 %) of total mGFFs. mGFFs from cereal mixture, buckwheat, corn and rice groups altogether seem the cause of the unacceptable figure of 17.5 %. Any ingredient group is supposed to be safe in terms of gluten

Table 3. Gluten concentration (G) of miscellaneous mGFFs according to the main ingredient groups (mg kg⁻¹). **Num:** Number of mGFFs; **Ratt:** Ratio of mGFFs in the total 200 (%), **Ratg:** Ratio of mGFFs in the main ingredient group (%).

Main ingredient group	Num Ratt	G < 20		G > 20		
		Num	Ratt	Num	Ratt	Ratg
		G < 5	G 5-20	G 20-40	G 40-80	G > 80
Cereal mixture	86	72	6	3	3	2
	43.0	36.0	3.0	1.5	1.5	1.0
		83.7	7.0	3.5	3.5	2.3
Buckwheat	42	10	8	10	1	13
	21.0	5.0	4.0	5.0	0.5	6.5
		23.8	19.0	23.8	2.4	31.0
Corn	38	31	5	1	1	-
	19.0	15.5	2.5	0.5	0.5	-
		81.6	13.2	2.6	2.6	-
Rice	23	19	3	1	-	-
	11.5	9.5	1.5	0.5	-	-
		82.6	13.0	4.3	-	-
Locust	6	6	-	-	-	-
	3.0	3.0	-	-	-	-
		100	-	-	-	-
Others	4	4	-	-	-	-
	2.0	2.0	-	-	-	-
		100	-	-	-	-
Potato	1	1	-	-	-	-
	0.5	0.5	-	-	-	-
		100	-	-	-	-
Total		143	22	15	5	15
		71.5	11.0	7.5	2.5	7.5
		100	100	100	100	100
	200	165		35		
	100	82.5		17.5		

contamination to produce and consume an acceptable mGFF with peace of mind.

The weight of mGFFs with a gluten content > 20 mg kg⁻¹ in the total (17.5 %) distributed as 4.0 % in the cereal mixture group, 12.0 % in the buckwheat group, 1.0 % in the corn group and 0.5 % in the rice group (Table 3). The weight of buckwheat in all unacceptable mGFFs was 68.6 % (24/35*100). Almost every 69 of 100 mGFFs contaminated with gluten are made from buckwheat. The weight of mGFFs with a gluten content > 20 mg kg⁻¹ in the group is 9.3 % for the cereal mixture, 57.2 % for the buckwheat, 5.2 % for the corn and 4.3 % for the rice (Table 3). Almost 57 out of 100 mGFF made from buckwheat were contaminated with gluten. The weight of buckwheat alone in mGFFs contaminated with gluten far exceeds the weight of cereal mixture, corn and rice. The cereal mixture is the second ingredient group having the most unacceptable mGFFs after buckwheat (4.0 % in the total, 9.3 % in the group). It is not known if the cereal mixture has

buckwheat or not in it. If buckwheat is excluded, the ratio of mGFFs with a gluten content > 20 mg kg⁻¹ would dramatically reduce to 6.3 % (11/176*100) from 17.5 % in the total (Table 3). It goes down to 1.8 % (3/168*100) if the suspicious cereal mixture is excluded too. These ratios are comparable with ratios for mGFFs contaminated with gluten recorded for other markets (Table 1).

Evaluation of buckwheat

The effect of buckwheat on the gluten contamination becomes more significant when it is examined with respect to product categories. Distribution of mGFFs made from buckwheat is provided in Table 4 for the product categories in the critical gluten content intervals, and also for certain gluten content intervals above 20 mg kg⁻¹ to present the level of the contamination due to buckwheat. Buckwheat was used in the production of 42 mGFFs in 6 of 8 product categories (7 in snack, 8 in pasta, 1 in bread, 14 in farina, 11 in traditional, 1 in others). Only in two categories (bread,

Table 4. Gluten concentration (G) of miscellaneous mGFFs made from buckwheat according to the product categories (mg kg⁻¹). **Num:** Number of mGFFs; **Ratt:** Ratio of mGFFs in the total 200 (%), **Rati:** Ratio of mGFFs in the product category (%).

Product category	Num Ratt	G < 20		G > 20		
		Num	Ratt	Num	Ratt	Rati
		G < 5	G 5-20	G 20-40	G 40-80	G > 80
Snack	7	4	-	1	-	2
	3.5	2.0	-	0.5	-	1.0
		57.1	-	14.3	-	28.6
Pasta	8	-	1	3	-	4
	4.0	-	0.5	1.5	-	2.0
		-	12.5	37.5	-	50.0
Bread	1	1	-	-	-	-
	0.5	0.5	-	-	-	-
		100	-	-	-	-
Farina	14	4	5	1	-	4
	7.0	2.0	2.5	0.5	-	2.0
		28.6	35.7	7.1	-	28.6
Traditional	11	1	2	4	1	3
	5.5	0.5	1.0	2.0	0.5	1.5
		9.1	18.2	36.4	9.1	27.2
Others	1	1	-	-	-	-
	0.5	0.5	-	-	-	-
		100	-	-	-	-
Total		11	8	9	1	13
		5.5	4.0	4.5	0.5	6.5
		26.2	19.0	21.4	2.4	31.0
	42	19		23		
	21.0	9.5		11.5		
	100	45.2		54.8		

others) all mGFFs have a gluten content $\leq 20 \text{ mg kg}^{-1}$ although with only one mGFF in each. Their number does not allow a conclusion that all mGFFs made from buckwheat in the bread and others categories are acceptable as this could be a coincidence. Other 4 product categories (snack, pasta, farina, traditional) have mGFFs from buckwheat both with a gluten content $\leq 20 \text{ mg kg}^{-1}$ and a gluten content $> 20 \text{ mg kg}^{-1}$. A significant portion of product categories (67 %) where buckwheat was used had unacceptable mGFFs, while the remaining 33 % (bread, others) is not clear if they have completely acceptable mGFFs. The ratio of mGFFs made from buckwheat with gluten content $> 20 \text{ mg kg}^{-1}$ is much higher than the apparent total ratio of 17.5 %. It is 42.9 % in the snack, 87.5 % in the pasta, 35.7 % in the farina, 72.7 % in the traditional categories. These figures would increase the ratio of unacceptable mGFFs if the effect of the suspect cereal mixture group is taken into account (Table 4).

Evaluation of measures

The ratio of unacceptable mGFFs made from buckwheat is very high according to all possible evaluations. Buckwheat seems the major cause of the gluten contamination issue in mGFFs produced in Turkey. Withdrawing its use would practically alleviate the issue to a great extent at least until the resolution of the problem. Verma et al. (2017) analysed miscellaneous mGFFs in the Italian market and Gelinis et al. (2008) analysed GF breakfast cereals in the Canada market for gluten content (Table 1). They emphasised the high risk of the gluten contamination from buckwheat in mGFFs. The use of buckwheat could possibly be a widespread problem in the production of mGFFs in other countries too and, worse, the gluten contamination from buckwheat may not be avoidable with today's handling and processing conditions.

Crop rotation and shared use of facilities and equipment are common practices in agriculture that may allow commingling and/or contact of GF and GC seeds. Shared and concurrent use of equipment and facilities in mills can lead to commingling of GF and GC flours. The shared use of facilities, equipment, concurrent manufacturing may give rise to mixing and/or contact of GF and GC raw materials and final

products. In short, agricultural, milling and manufacturing practices alone or in any combination may be the source of the gluten contamination in mGFFs.

In studying gluten contamination in buckwheat, Ulutas (2019) detected gluten content $\leq 20 \text{ mg kg}^{-1}$ in whole buckwheat seeds packaged and marketed in Turkey with the claim of GF. Although we found that specific manufacturers have produced unacceptable mGFFs made from buckwheat, the same manufacturers are able to produce acceptable mGFFs from ingredients other than buckwheat under the very same conditions (Table 5). For example, for manufacturer A, the ratio of unacceptable mGFFs is 83.3 % for buckwheat, 2.9 % for cereal mixtures, and 0.0 % for corn, rice and others. For manufacturer D, it is 42.9 % and 0.0 % for buckwheat and cereal mixture, respectively. Other manufacturers had almost the same results. Though three possible sources given could be responsible, the milling operation may be speculated to be the main source of the gluten contamination in mGFFs. mGFF-producers generally would rather use buckwheat flour assuming it is GF with no proof. They are not able to know the history of buckwheat flours. Instead, they are advised to prefer to have whole seeds to mill in their own GF facilities. It also protects their facilities and mGFFs made there from other ingredients against gluten contamination.

The general scenario would be even worse if gluten content of mGFFs were evaluated according to the above suggested limit of 5 mg kg^{-1} . Any ratio for acceptable mGFFs would get much smaller (71.5 %) and for unacceptable mGFFs would get much greater (28.5 %) (Table 2). Though according to the effective regulation, the limit of 20 mg kg^{-1} is enough, gluten content $5\text{--}20 \text{ mg kg}^{-1}$ is a robust sign of the gluten contamination. The gluten contamination issue in GFFs is a critical problem for both mandatory and voluntary GFF-consumers not only in Turkey but also in other countries, too (Table 1). The gluten contamination in GFFs is not a technical matter; rather it is a regulatory matter. Producing acceptable mGFFs together with unacceptable mGFFs is a strong indicator to the technical ability of manufacturing mGFFs without gluten contamination (Table 5). The issue could readily be resolved by an amendment in the current regulations (TFC 2012; FDA 2013; EC 2014) by enforcing preventive activities.

Table 5. Gluten concentration (G) in miscellaneous mGFFs according to manufacturers* and the main ingredient groups (mg kg^{-1}). **Num:** Number of mGFFs manufactured by the specified manufacturer, **Rati:** Ratio of mGFFs in the main ingredient group (%).

Manufacturer Num	Main ingredient group	Num Rati	G < 20 Num Rati		G > 20 Num Rati		
			G < 5	G 5–20	G 20–40	G 40–80	G > 80
A 71	Buckwheat	24	1	3	8	1	11
		33.8	4.2	12.5	33.3	4.2	45.8
	Cereal mixture	35	31	3	1	–	–
		49.3	88.6	8.6	2.9	–	–
	Corn	7	5	2	–	–	–
		9.9	71.4	28.6	–	–	–
	Rice	2	1	1	–	–	–
		2.8	50.0	50.0	–	–	–
	Others	3	3	–	–	–	–
		4.2	100	–	–	–	–
B 11	Buckwheat	6	–	5	1	–	–
		54.5	–	83.3	16.7	–	–
	Cereal mixture	5	5	–	–	–	–
C 18	Buckwheat	5	5	–	–	–	–
		27.8	100	–	–	–	–
	Cereal mixture	13	4	3	2	2	2
D 9	Buckwheat	72.2	30.8	23.0	15.4	15.4	15.4
		7	4	–	1	–	2
	Cereal mixture	77.8	57.1	–	14.3	–	28.6
		2	2	–	–	–	–
		22.2	100	–	–	–	–

*Manufacturers using both buckwheat and other main ingredients in their facilities.

The current regulations focus on post-market activities such as sampling, periodic inspection, label reviews, following up complaints, and analysis when needed, etc. to check if a GFF is really GF as claimed. Such activities do not protect GFF-consumers from consuming GFFs contaminated with gluten and they could readily become victims of the consumption until such activity stops. The current regulations do not force the mGFF-producers to determine gluten content in their raw materials and final products. They just keep the manufacturers responsible for ensuring the GF claim is correct. Pre-market activities such as enforcing to do so and prohibiting releasing of mGFFs with a gluten content $> 20 \text{ mg kg}^{-1}$ into the market would be more effective. The food contamination issue should be under the strict control of the regulation even if the beneficiary focus group is in a minority.

Even one mGFF contaminated with gluten in a product category and/or in an ingredient group has enough potential to make GFF-consumers suspicious of all mGFFs produced in a country. Enforcing pre-market practices is in favour of mGFF-producers meeting the

regulation will distinguish them from others not meeting it. The enforcement is also for the benefit of producers who are not able to meet the regulation by providing an opportunity to be aware of the issue and to be part of the solution rather than the issue.

Conclusions

A significant proportion of mGFFs produced in Turkey (17.5 %) have a gluten content $> 20 \text{ mg kg}^{-1}$, e.g. they are contaminated with gluten and unacceptable. Mandatory GFF-consumers must not consume them for their health and well-being. Both mandatory and voluntary GFF-consumers do not wish to consume them but are being cheated economically. Buckwheat is the main culprit for the high ratio of unacceptable mGFFs produced in Turkey. If it is not used, the ratio of mGFFs contaminated with gluten drops dramatically and would go down to 6.3 % (probably to 1.8 %) which is easily comparable with the proportions reported for other countries. The issue of gluten contamination is experienced all over the world, and it could readily be resolved to a great extent if the current regulations are amended to focus on pre-market practices together with post-market

practices. The amendment could enforce mGFF-producers to detect gluten content in their raw materials and final products, and deprive them of releasing unacceptable mGFFs into the market. This work is an initiative for the Turkish market and the level of the issue was not established for the majority of markets. Surveys for detecting gluten contamination in GFFs should be conducted periodically for every market to assess the problem and contribute to the resolution of the issue.

Acknowledgments

Authors dedicate this work to gluten sufferers and their families by appreciating how a GF-life is challenging, and gratefully acknowledge the support of University of Mersin under the Project 2015-TP2-1243.

Declaration of Interest Statement

We, the authors of the manuscript, are reporting that we have no potential conflict of interest with any party including but not limited to any person, corporation, organization, and institution.

ORCID

Guler Atasoy  <http://orcid.org/0000-0001-8032-0052>
Ozge Kurt Gokhisar  <http://orcid.org/0000-0002-2400-5848>
Mahir Turhan  <http://orcid.org/0000-0001-6664-2223>

References

- Atasoy G. 2017. Türkiye'de satılan glutensiz gıdalarda fiyat ve gluten araştırması [A market and gluten contamination research in gluten free foods on Turkish market] [master's thesis]. Mersin (Turkey): University of Mersin. Turkish.
- Australia New Zealand Food Standards Code. 2014. Australia New Zealand Food Standards Code: standard 2.9.5. Food for special medical purposes. Australia: Australian Government Federal Registration of Legislation; accessed 2019 Nov 25. <https://www.legislation.gov.au/Details/F2014C01202>
- Bai J, Fried M, Corazzo G, Schuppan D, Farthing M, Catassi C, Greco L, Cohen H, Ciacci C, Eliakim R, et al. 2013. World gastroenterology organisation global guidelines on celiac disease. *J Clin Gastroenterol*. 47(2):121–126. doi:10.1097/MCG.0b013e31827a6f83.
- Bustamante MA, Fernandez-Gil MP, Churrua I, Miranda J, Lasa A, Navarro V, Simon E. 2017. Evolution of gluten content in cereal-based gluten-free products: an overview from 1998 to 2016. *Nutrients*. (9):21–33. doi:10.3390/nu9010021.
- Catassi C, Fabiani E, Iacono G, D'Agate C, Francavilla R, Biagi F, Volta U, Accomando S, Picarelli A, De Vitis I, et al. 2007. A prospective, double-blind, placebo-controlled trial to establish a safe gluten threshold for patients with celiac disease. *Am J Clin Nutr*. 85:160–166. doi:10.1093/ajcn/85.1.160.
- [Codex] Codex Alimentarius. 2015. Codex Standard for foods for special dietary use for persons intolerant to gluten, CODEX STAN 118-1979. (revised 2008, amendment 2015). accessed 2019 Oct 21. http://www.fao.org/input/download/standards/291/CXS_118e_2015.pdf.
- [EC] European Commission. 2014. Commission implementing regulation (EU) No 828/2014, requirements for the provision of information to consumers on the absence or reduced presence of gluten in food. *Off J Eur Union L*. 228:5–8.
- Farage P, Nobrega YKM, Pratesi R, Gandolfi L, Assunção P, Zandonadi RP. 2016. Gluten contamination in gluten-free bakery products: A risk for coeliac disease patients. *Public Health Nutr*. 20(3):413–416. doi:10.1017/S1368980016002433.
- [FDA] Food and Drug Administration. 2013. U.S. government publishing office 78 FR 47154-food labeling; Gluten-free labeling of foods. *Fed Regist*. 78 (150):47154–47179. [accessed 2019 Oct 22]. <https://www.govinfo.gov/app/details/FR-2013-08-05/2013-18813>.
- Gelinas P, McKinnon CM, Mena MC, Mendez E. 2008. Gluten contamination of cereal foods in Canada. *Int J Food Sci Tech*. 43:1245–1252. doi:10.1111/j.1365-2621.2007.01599.x.
- Gursoy S, Guven K, Simsek T, Yurci A, Torun E, Koc N, Patisroglu TE, Ozbakir O, Yucesoy M. 2005. The prevalence of unrecognized adult celiac disease in Central Anatolia. *J Clin Gastroenterol*. 39(6):508–511.
- Koehler P, Schwalb T, Immer U, Lacorn M, Wehling P, Don C. 2013. AACCI approved methods technical committee report: collaborative study on the immunochemical determination of intact gluten using an R5 Sandwich ELISA. *Cereal Food World*. 58(1):36–40. doi:10.1094/CFW-58-1-0036.
- Kraushaar A. 2015. Pasta, rice and grains, issues and insights: annual report. Mintel Store; accessed 2019 Feb 5. <https://store.mintel.com/pasta-rice-and-grains-us-april-2015>.
- Lambert K, Ficken C. 2016. Cost and affordability of a nutritionally balanced gluten-free diet: is following a gluten-free diet affordable? *Nutr Diet*. 73:36–42. doi:10.1111/1747-0080.12171.
- Lee AR, Ng DL, Zivin J, Green PH. 2007. Economic burden of a gluten-free diet. *J Hum Nutr Diet*. 20(5):423–430. doi:10.1111/j.1365-277X.2007.00763.x.
- Lee HJ, Anderson Z, Ryu D. 2014. Gluten contamination in food labelled as 'gluten free' in the United States. *J Food Protect*. 77 (10):1830–1833. doi:10.4315/0362-028X.JFP-14-149.
- Mattioni B, Scheuer PM, Antunes AL, Paulino N, Francisco A. 2016. Compliance with gluten-free labelling regulation in the Brazilian food industry. *Cereal Chem*. 93 (5):518–522. doi:10.1094/CHEM-08-15-0158-R.
- Miller D. 2016. Maybe it's not the gluten. *JAMA Intern Med*. 176(11):1717–1718.

- Ministry of Food, Agriculture and Livestock of Turkey. 2017. Control of import commodities subject to inspection by the Ministry of Food, Agriculture and Livestock of Turkey. accessed 2019 May 10. <https://kms.kaysis.gov.tr/Home/Goster/139283>.
- Mintel. 2015. Half of Americans think gluten-free diets are a fad while 25% eat gluten-free foods. Mintel Press Office; accessed 2019 Mar 9. <http://www.mintel.com/press-centre/food-and-drink/half-of-americans-think-gluten-free-diets-are-a-fad-while-25-eat-gluten-free-foods>.
- Mintel. 2016. Gluten-free Foods - US. Mintel Academic; accessed 2019 Mar 9. <http://academic.mintel.com/display/748050/#>.
- Molina-Infante J, Santolaria S, Sanders DS, Fernández-Banares F. 2015. Systematic review: noncoeliac gluten sensitivity. *Aliment Pharm Ther*. 41:807–820. doi:10.1111/apt.13155.
- Norelle RR. 2016. The gluten-free diet: recognizing fact; fiction and fad. *J Pediatr*. 175:206–210.
- Panagiotou S, Kontogianni MD. 2017. The economic burden of gluten-free products and gluten free diet: A cost estimation analysis in Greece. *J Hum Nutr Diet*. 30:746–752. doi:10.1111/jhn.12477.
- R-Biopharm. 2019. Ridascreen Gliadin Art No: 7001. Darmstadt (Germany): R Biopharm AG. accessed 2019 Jun 7. <https://food.r-biopharm.com/products/ridascreen-gliadin/>.
- Sapone A, Bai JC, Ciacci C, Dolinsek J, Green PH, Hadjivassiliou M, Kaukinen K, Rostami K, Sanders DS, Schumann M, et al. 2012. Spectrum of gluten-related disorders: consensus on new nomenclature and classification. *BMC Med*. 10:1–12.
- Sharma GM, Pereira M, Williams KM. 2015. Gluten detection in foods available in the USA-A market survey. *Food Chem*. 169:120–126. doi:10.1016/j.foodchem.2014.07.134.
- [TFC] Turkish Food Codex. 2012. Gluten intoleransı olan bireylere uygun gıdalar tebliği No: 2012/4, 28163 (Communiqué on foods suitable for individuals with gluten intolerance) accessed 2019 Oct 21. <https://www.resmigazete.gov.tr/eskiler/2012/01/20120104-8.htm>.
- Ulutas B. 2019. Karabuğdayda temas yoluyla oluşabilecek gluten bulaşısının incelenmesi [Gluten contamination in buckwheat through contact with gluten containing seeds and gluten contaminated surfaces] [master's thesis]. Mersin (Turkey): University of Mersin. Turkish.
- Verma AK, Gatti S, Galeazzi T, Monachesi C, Padella L, Giada Del B, Annibali R, Lionetti E, Catassi C. 2017 Feb. Gluten contamination in naturally or labelled gluten free products marketed in Italy. *Nutrients*. (9):115–125. doi:10.3390/nu9020115.