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FOOD INTEGRITY CONCEPT IN WHEAT PROCESSING

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Abstract

The present paper aims to analyze the concept of "food integrity" from the perspective of wheat processing, in order to obtain flour. The analysis approaches concepts such as: safety, quality, authenticity and nutritional value of the products obtained to the main technological stages of the grinding process, food fraud concerning grinding products and minimization of the milling industry impact on global warming. Our data showed that mycotoxin contamination (DON and Ochratoxin A) was the cause of most alerts recorded in Europe. In United States, the main products withdrawals were caused by microbiological contamination (E. coli and Salmonella). In the area of food fraud, the main observed practice was that of over- or under-evaluation of the flour mineral content. Our conclusion is that although preventive programs, designed to minimize the risks of wheat milling products to consumers, are well described and implemented, there is room for improvement, especially as regards the selection and evaluation of suppliers and the control of certain microbiological risks in mills.Most of the problemsare the causeof an inadequate description of the flow diagrams in the specific documentation of food management systems and of the underestimation of certain activities (e.g.rework), that are not treated as an integral part of the technological processes in mills.Most concerns to reduce the impact of wheat processing on global warming are compromised by a number of issues, such as large investments, in obtaining convenient and safer products (that require energy-intensive technologies and equipment), which are in contradiction with consumers' interest.

Keywords*:food integrity, wheat, wheat flour*

INTRODUCTION

The application of the food integrity concept to wheat and derived products is relatively complex due to the presence of specific conditions. The notion of food integrity is constantly redefining as both science evolves towards introducing new concepts and as to consumers' concerns about safety, quality and authenticity of food are added, namely: chain food transparency, nutritional value of food, environmental impact (life cycle assessment), cultural factors related to beliefs, traditions, social and geographic factors. The condition that determined the evolution of wheat processing in mills, in the industrial age, is of an economic nature, respectively to obtain the highest added value for the processed products [15]. This has led to a cyclical evolution in the industry. If at the beginning of the industrial era, the main objective was to grind the grains, in order to obtain as much flour as possible (by using mainly whole flours), as the flour became more and more cheap, the companies turned to refine it, in order to obtain whitish flours, associated with the idea of purity and health [17].Advanced cereals grinding is associated with loss of vitamins and minerals. At this moment, the evolution is contrary, the added value is seeked in whole flours or in mixtures of flours, from different cereals or pseudo-cereals, with functional food attributes. Hyperprocessing food through innovation and creation of new technologies has transformed the food industry into an anteroom of the digestive system.It has been invested in foods that reduce the need for physiological processes that play a key role in food metabolism, such as mastication, food bowl formation and digestion. These processes have exponentially increased the vulnerability

of food to factors such as biological, chemical or physical contamination and have disturbed the consumer in relation to his traditional consumption habits. These vulnerabilities have raised concerns in researching and implementing ways to prevent and control the risks of production-related food safety, such as HACCP or ISO 22000, IFS, BRC, etc.

Practically, as the food industry has become an antechamber of the digestive system, concerns have also grown for building an adequate immune system to protect this system [18].

This paper aims to analyze the concept of "food integrity" in the wheat processing industry, in order to obtain one of the basic food, namely wheat flour.

MATERIALS AND METHODS

This paper presents a review from the literature, on one of the most interesting concepts, namely "food integrity". In this respect a large number of statistical data from public sources have been studied: alerts from the American Food and Drug Administration, FDA, from European Food Safety Authority EFSA, scientific papers relevant to food safety in industry, specific provisions of the main management systems (FSSC 22000, BRC, IFS etc.), related scientific work in the fields of consumers behavior, medical nutrition, ecology etc.

RESULTS AND DISCUSSIONS

An analysis of food alerts on the RAFFS (European Commission's Food and Feed Safety Alerts) portal shows that out of over 48.000 alerts recorded between 2001 and 2017, only 1905 (3.94%) involved cereals and bakery products. Of these, only 76 (3.99%) involved wheat and wheat flour. The highest number of alerts were linked to the **contamination of wheat or flours with mycotoxins** (46%) (Fig.1). Of the mycotoxin alerts, 60.61% had as object deoxynivalenol (DON) contamination, 33.3% Ochratoxin A contamination, and 2 alerts were related to exceeding the quantity of total aflatoxins or to presence of Claviceps Purpurea ergot.

The second category of problems identified is related to **contamination with foreign bodies**, including infestation (insect larvae and mice). From the category of foreign bodies that have been subject to contamination, except for infestation (31.25%), most problems were related to the presence of ferromagnetic impurities (25%), copper yarns (12.5%), plastic, glass, stones or asbestos containing materials.Contamination with pesticide residues represents 10% of the total number of alerts (diclorvos, dithiocarbamates, fenitration, diazinona or permethrin).We have included in this category an alert related to benzo(α)pyrene and aromatic polycyclic hydrocarbons, whose source can be pesticides, although their major environmental impact is due to other sources.

Metallic contamination (8% of the total number of alerts) had as object the exceeded limits allowed for Lead, Cadmium and Aluminum, especially for products imported from South East Asia (China, Thailand, Vietnam).

Contamination with soybeans (undeclared allergen) was a 7% alerts problem. Soybean contamination is more common in countries where bakeries use cereal flours mixtures or various seeds, to obtain specific bakery products.

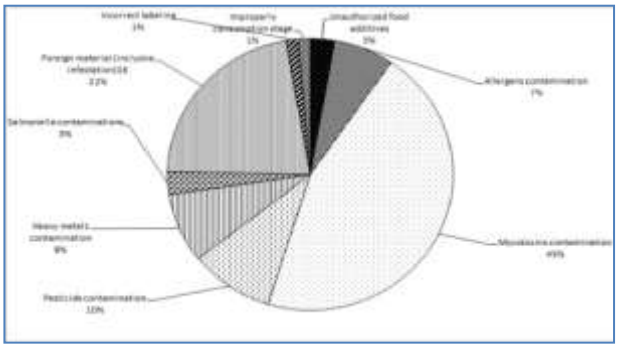

Figure 1. The main European food alerts on wheat flour
Source: Our design based on literature data.

The **unauthorized additives** were the object of 4% of alerts. The presence of unauthorized additives such as benzoyl peroxide, chlorine, calcium peroxide etc., is a problem related to imports from USA, a country where their use in flours correction is allowed.

There have been two **Salmonella contamination** alerts in wheat flour from

Germany (29.01.2016) and in some cereals flours from Ghana (11.07.2005).
Two other alerts concerned the inappropriate labelling of Spelta wheat flour (Austria) and also the improper stage for consumption of a red spring wheat coming from Canada. The main US alerts are shown in Table 1.

Table 1. Main food alerts in USA related to wheat flour

Company	Year	The alert type	Presentation
General Mills	2016	Microbial contamination (E coli)	General Mills withdrew between 4.5 and 7.0 million tons of flours infested with E Coli O121. The strain caused the illness of 68 people in 24 states, 17 of them requiring hospitalization and one developing hemolytic uremic syndrome. The source of the disease was contact or ingestion of raw dough prepared from wheat flour [2, 7]
Grain Craft	2016	Undeclared allergen (peanut proteins)	The traceability analysis showed that the flours came from wheat obtained in an area recognized for the intense cultivation of peanuts, in Georgia [6, 21]
T-Brothers Food and Trading Ltd	2016	Undeclared allergen / foreign bodies (milk powder and sesame seeds)	Mixtures of flours for domestic use [19, 8]
Morisson Milling Company	2016	Foreign bodies	Nylon threads from a mill sieve breakage
King Arthur Flour	2013	Foreign bodies	Presence in flour of some mill shakers (9 mm polyurethane balls used to facilitate the sifting process)
Arrowhead Mills Inc	2012	Undeclared allergen (milk powder)	Whole wheat flour grinded on a stone mill
Nestle	2010	Microbial contamination: E coli O157: H7	The source of the illness was a raw dough made by Nestle. It has led to the illness of 72 people in 30 US states [5]

Source: Our design based on literature data.

As can be seen in the table, the main issues in USA were related to microbiological contamination,contamination with allergens and to the presence of foreign bodies.The source of some of these problems is the raw materials used, respectively the poor management in their obtaining. The usual analyzes made at the cereals reception in the mills are not able to identify the risks mentioned above.

These analyzes focus on controlling technological potential of the raw material, but are limited concerning food safety problems, detectable by olfactory analysis of wheat samples. In Table 2 are presented the main analyzes that are made at the reception of wheat in the mills, respectively some comments on their adequacy in food safety management.

Table 2. The main methods of analysis used for the wheat reception in mills

Analysis method	Standard	Technological relevance	Relevance for food safety
Sensorial (smell, colour)	ISO 7970	Reduced	Essential, it can highlight processes of alteration, microbial proliferation, heating, contamination with pesticides or foreign substances, massive attack by Fussarium sp., Tilletia tritici, Claviceps purpurea, etc.
Infestation	ISO 6639	Prevents the infestation with larvae or adults	Essentially, it is a synthetic criterion of how cereals have been conditioned; insects can be vectors to transfer microbial pathogens from contaminated areas to uncontaminated areas of the mill.

Table 2. The main methods of analysis used for the wheat reception in mills (contuinued)

Analysis method	Standard	Technological relevance	Relevance for food safety
Foreign bodies (%)	ISO 7970	High impact, significantly influences the economic balance of the grinding process	High, prevents contamination of milling products with toxic seeds
Moisture (%)	ISO 711 ISO 712	High impact, influences the economic balance of the grinding process	High, the increase of the humidity over 14.5% leads to the intensification of the microbial metabolism, decreases the storage duration of the seeds
Hectolitric Mass (kg/hl)	ISO 7971	Certain scientific studies, but also a series of empirical evidences correlate the value of this parameter with extraction	Without significance
Falling Number (Hagberg, s)	ISO 3093	High, the parameter is correlated with the wheat baking potential. Granules with a low value of 180 s are considered unmatched due to intense amylase activity	Without significance
Protein content (%)	NIR method, ISO 16634-2:2016	High, the parameter is correlated with the wheat baking potential	Without significance
Wet gluten (%)	ISO 7495	High, the parameter is correlated with the wheat baking potential	Without significance
Gluten index	AACC 38-121	High, the parameter is correlated with the wheat baking potential	Without significance, very low values could be an indication of insect attack (Eurygaster sp.)
Rheological analyzes (following the grinding of the wheat sample, whether conditioned or not, on a pilot mill and extraction of flour)	Farinograf - ISO 5530-1 Amylograph ISO 7973 Alveograf ISO 27971 Mixolab ISO 17718 Extensograf ISO 5530-2	High, strong correlation with the quality characteristics of the flour and the obtained products	Without significance, very low values of rheological parameters may be associated with high levels of enzyme activity, induced by insect attack or microbial contamination (fungi, bacteria)

Source: Our design based on literature data.

Since wheat flour is not considered to be a fully processed and ready-to-eat foodstuff, there is a tendency for none of the risks of the type mentioned in Figure 1 and Table 1 to be monitored by critical control points (CCP). Generally, the practice is to manage these risks inprerequisite and operational prerequisite programs such as: pest control, surface and machinery hygiene, control of environmental conditions in production and storage areas, water quality control, maintenance of equipment, control of packaging conditions, transportation etc [4, 10].

There are sufficient opinions that consider the flour system to be a closed system, or with a minimum number of areas where product contamination can be achieved. In fact, there are at least three technological steps in which the product may be contaminated with non-wheat substances or microorganisms, namely: cereals conditioning, at which point wheat is mixed with water to achieve optimal moisture for the grinder; dosing the ingredients or additives used for the correction of flour;

packing, when the product comes into contact with the walls of bulk carriers or with the walls of the packages.In addition, in the absence of a truly effective pest control system, pathogenic microorganisms (e.g. Salmonella) are translocated by insects along the technological flow, due to their natural mobility [16, 20]. There are a multitude of studies that prove the vector status of insects in the mills, for pathogenic microorganisms, taking into account the context of ecological relationships involving insects.For example, the transfer of pathogenic microorganisms from birds, which have their geographic area in the area where the mill is built, to insects, should not seem unlikely [3, 22]. Insects have the ability to contaminate specific products at different stages of the flour production, creating a risk associated with the natural habitat characteristics for the mill (presence of nearby municipal waste, sewage treatments, landfills, etc.) (Fig. 2).

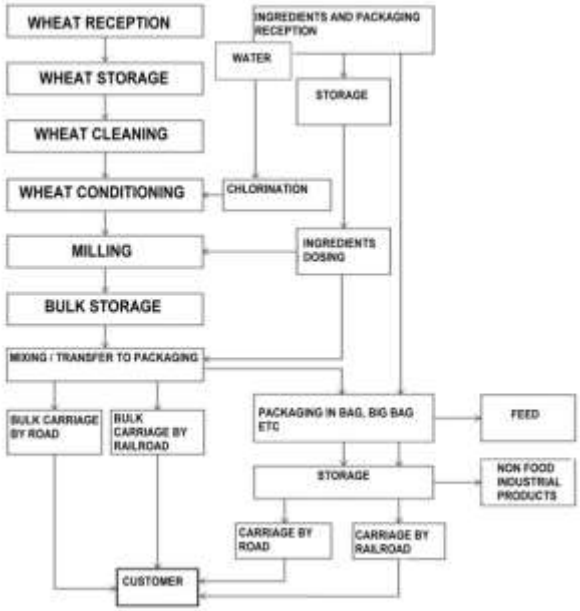

Figure 2. The technological scheme for wheat processing in the mills (after Mortimore and Wallace, 2013)

The tendency to eliminate critical control points from food management systems in wheat flour obtaining, given the fact that production processes are subjected to controllable risks through regular prevention programs, is a sign of industry and authorities superficiality. This is understandable if we look at the issue in the context of the examples presented previously, for the European and North American markets.

For neither of the most common problems, food safety systems lack effective prevention and control tools. Contamination with mycotoxins, pesticides, heavy metals, allergens or potentially pathogenic microorganisms is a managed risk at merchandise reception, due to sensorial control, to the quality documents accompanying the product and the presumption that the agreed supplier was eventually audited and performs himself a specific control of the goodshe sells.

Wheat reception in mills is limited to assessing the technological potential of raw material, the system being focused on quality assurance and less on account of ensuring consumer safety. Even specific legislation does not impose, for example, microbiological criteria appropriate to potential risks to the consumer. In Romania, the contamination with yeasts and molds (in fact, an insignificant criterion for the evaluation of the wheat microbiological safety) is still an obsession of the authorities, despite the fact that microbiological alerts in the world, concerning the flours, are mainly around the strains of Salmonella and E. coli [1]. From this point of view, there is certainly place for significant improvements.

We can appreciate that the most frequent problems, related to the management systems of food safety in the production of wheat flours, are based on important errors in the conception, implementation and maintenance of these systems. Many of these systems are too complicated and difficult to maintain. They are based on one person's control, process discrimination and the transfer of responsibility to a sufficient number of people is limited.Thus, there are problems related to the technological flow and to the evaluation of the viability and functionality of the food safety management system. On the other hand, certain flow diagrams are incorrect, because there is a tendency to simplify flow diagrams, to hide certain practices that may seem unethical, or may create complications in relation to authorities or third part auditors.

Such a case is the flours reprocessing, a practice whose necessity is sometimes determined by the characteristics of the technological flow (physical blockage of the transport routes in the mill, flour recovered from the packing unit, as a result of bags or sacks breakage etc.).The lack of this stage in the technological flow is vulnerable to the system and exposes it to unrated risks. From our point of view, it is obligatory to pass the reprocessed flours through impacting entoleters.

In many situations, for the water used in wetting purposes (wheat wetting), the need for chlorination is not specified.The quality of the water used in the mill must comply with the requirements of the drinking water legislation.Even under these circumstances, due to the microbial load of wheat grain, water chlorination is strictly necessary, precisely to limit the development of microorganisms in the wheat resting stage. This stage lasts 16-18 hours and ensures ideal humidity and temperature conditions for microorganisms multiplication.

Relevant research in the field, such as the addition of certain substances, like lactic acid or its salts, which could be useful in reducing microbial growth at this level, should be taken into account.

Certainly, proper hygiene and hygiene monitoring programs, for all the infrastructure used in this process, must be introduced, namely: dampening screws, transfer elevators, tempering silo, feeding bunks etc.

In many situations, we are dealing with a poor understanding of the intrinsic factors that ensure the consumption safety of the flour.Many millers believe that providing less than 14.5% humidity is a sufficient condition to eliminate the risks related to consumer safety. However, this moisture does not eliminate a potential infestation of flour with insects, in the egg stage or with microorganisms in the form of spores.

To these, a number of factors already mentioned in the literature are added as frequent sources of poor efficiency of food safety management systems, namely: poor attention paid to the verification process, insufficient support from top management, lack of workers involvement etc [12].

One of the key issues in the field, at least in Romania, is related to **food fraud**. Specific legislation prohibits the use of the term "type" in the milling products labelling, for the final consumer (Government Decision, GD 106/2002 on food labelling) [11]. This prohibition leaves a wide maneuvering space to flour producers or users. A lot of food labels, food in which wheat flour is used, does not provide the consumer any element to suggest the technological conditions underlying it. The information are like: "white wheat flour", or "dark wheat flour", or "whole wheat flour". The problem is highlighted in one of our previous studies, where we found that in 50% of the flours available to Romanian end-users, the mineral content did not match with the names under which the flour was sold [24].The problem particularly touches the extremes: a flour marketed as whole flour was found to be dark flour (Ash=1.21%), a flour marketed as dark flour was actually half-white flour (Ash=0.97%), and seven flours marketed as “flour 000” had ashes between 0.51 and 0.59 (ashes that correspond to 550 and 650 types flours).

These practices hide economic interests, namely: the sale of high extraction flours as low extraction flours, or the sale of some unsuitable flours as high value added flours, in the absence of suitable technologies to obtain them (dark flour sold as whole flour) [24].The consumer's ability to notice the flour quality differences is minimal, because the colour of the flour is a parameter that does not necessarily and always depend on the extraction degree. Modern technologies, such as the use of the debranner, prior to the introduction of wheat to the grinding, these molina efficient cleaning, or even the addition of specific additives that can oxidize the flour pigments, can significantly influence the whiteness of the grain.

Another problem is related to how the milling industry is involved in the global issue of reducing energy costs, in the context of global warming concerns.Although most studies conclude that on the wheat-flour-bread production line, the majority of energy

consumption occur on the edges of this line (namely: phytotechnics and logistics related to wheat storage and transport to the mill, in the bread-making technologies and associated logistics to the consumer). This being said, it is seen that milling is far from being a small energy consumer [14].The amount of energy consumed over the entire line exceeds 19,000 MJ/tonne of flour, equivalent to ,800 kg of CO_2 per tonne of flour.Flour production only is responsible for about 11-12% of this quantity of energy, of which the effective grinding has a share of 2-7% (361-1,186 MJ). At the level of the entire European Union, the energy consumption related to the wheat milling has a value of between 103 and 337 million euro (2.9-9.3 euro/tonne of flour and 0.7-2.2% of the domain turnover) [23].

Globally, the total energy consumption of wheat mills is estimated at 37.5 billion KW/h, representing 0.2% of total electricity consumption [9].

In Romanian mills, the current average consumption is estimated at 80-100 kWh per tonne of grinded wheat, which means that about 300 million kWh of electricity is consumed annually [13].Energy consumption in mills is dominated by a number of technological features, namely: the total processing capacity (the size of the grinding section), the share of the pneumatic transport, the automation degree, the machinery mode of operation (individually, by groups etc.) and the total compressed air consumption. All of this may lead to significant differences between the specific energy consumption in mills.

Generally, modern technologies that allow to obtain higher extraction flours, as well as reduction of microbial load, contaminant quantities (pesticides, mycotoxins, heavy metals) or viable insect eggs from finished products, using wheat debranners and entoleters, require significantly higher energy consumption than conventional technologies.This is one of the issues where modern technologies, that can help the increase of consumer's food safety, do not necessarily reconcile with concerns for environmental preservation. As energy costs increase, mills will be interested in new technologies that reduce energy consumption of the grinding process. This transition involves significant investments, and in some cases even the complete refurbishment of some sections: the transition from two-engines valves to single-engine valves, the replacement of compressors or fans with frequency control equipment, the replacement of pneumatic driving with electric ones, the use of high efficient-low energy electric motors etc.

Therefore, from the perspective of consumers expectations, to increase the safety of food products, the technological developments in industry, related to the possibility of reducing the impact on global warming, are relatively difficult to implement, as it involves significant investments to replace existing infrastructures.

CONCLUSIONS

Although preventive programs aimed to minimize the risks for consumers,caused by wheat milling products, are well described and implemented, there is room for improvement, especially with regard to the selection and evaluation of suppliers and to the control of certain microbiological risks in the mills.

Most of the problemsarises from an inadequate description of the flow diagrams, in the specific documentation of food management systems, i.e. the underestimation of certain activities (eg rework),which are not treated as acontinuous and integral part of the technological processes in the mills.Some loopholes in the legislation allow deviations of finished products from standards.

In the field of food fraud, the sale of wheat flours with a mineral content of higheror less than the amount of mineral substances, required by the name of the product, is frequent.

Industry developments in terms of reducing energy costs,in order to diminish global warming, are relatively slow,as they need large investments and oppose efforts to increase food safety, that require high-energy equipment (wheat debranner, entoleter etc).

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