International Journal of Food Microbiology 239 (2016) 113–124

Contents lists available at ScienceDirect

International Journal of Food Microbiology

journal homepage: www.elsevier.com/locate/ijfoodmicro

Nutritional therapy – Facing the gap between coeliac disease and gluten-free food

Martina Foschia [1], Stefan Horstmann [1], Elke K. Arendt *, Emanuele Zannini

Food and Nutritional Sciences, National University Cork, College Road, Cork, Ireland

ARTICLE INFO

Article history:
Received 21 January 2016
Received in revised form 10 June 2016
Accepted 13 June 2016
Available online 15 June 2016

Keywords:
Coeliac disease
Gluten-free ingredients
Sourdough
Dough quality
bread

ABSTRACT

The market of gluten-free bakery products is considerably growing since better diagnostic methods allow identifying an increasing number of people suffering coeliac disease and other gluten-related disorders such as dermatitis herpetiformis, gluten ataxia, wheat allergy and non-coeliac gluten sensitivity. The only and safe treatment available nowadays for these types of disorders is to follow a strict and permanent lifelong gluten-free diet. Beside the people needing to follow a gluten-free diet for health reasons, a new segment of consumers has arisen who consume gluten-free products as a lifestyle choice. Among the bakery products, bread is a major staple food consumed daily all over the world. The dough and bread quality characteristics (such as gas retaining ability, mixing tolerance, resistance to stretch and extensibility and crumb structure) are mostly attributed to the presence of gluten. Despite the improved quality of gluten-free breads in the last number of years, most products on the market are still described as low quality product. In addition to the low overall quality of gluten-free products, the nutritional value of a large number of them is quite poor. In this context, this review gives an overview on the consumers, which need to follow a gluten-free diet for health reasons. The trends in this gluten-free bakery segment will also be reviewed based on the current analysis of marketing studies. An overview of the major ingredients used in gluten-free bread products will be given. The choice of the ingredients discussed in this paper is based on a comprehensive study of the leading gluten-free breads available on the market, as well as a detailed study of the scientific literature. The impact of the various ingredients on bread-making process and bread quality is also part of this review. Major emphasis will be placed on the application of sourdough as a means to improve gluten-free bread quality.

1. Introduction

Coeliac disease (CD) has become an intensively researched topic over the last years. In fact, a search on "Google Scholar" with the topic "Coeliac disease" resulted in 15,900 articles in the period between 2000 and 2010. The same search for the period between 2010 and 2015 resulted in 17,500 articles, stating that more research was conducted in the last five years than in the 10 years before.

Based on the advanced and evolving technologies more people are diagnosed with CD and related diseases. The constant increase of the gluten-free market is also due to the consumption of these products from the family members and friends of coeliac patients and healthy consumers, who eat gluten-free products as a life style (Arranz et al., 2015). While patients suffering from gluten-related diseases rely on a gluten-free diet, other consumers choose to follow it as a lifestyle choice, as it evokes a cultural-,ecological, civic-, historical-, ethnical- or health-based interest of quality (Worosz and Wilson, 2012). All these factors promote the gluten-free market and its continuing growth.

A recent report (Mintel, 2015) on the growing gluten-free market revealed that the expected sales were reached and are still growing. The report stated a gluten-free food category growth of 136% between 2013 and 2015 reaching $11 billion, currently. Based on the fact that food manufacturers introduce new products to the market and start to label their existing ones the share of gluten-free foods in the food category continues to grow. The Mintel report also offers predictions of total sales in the US until 2018 (Fig. 1), with the worst case scenario still reaching an increase of almost a fifth (18.1%).

In this context, the present review will present a general overview of CD and other gluten-related disorders moving then towards the analysis of the most promising approaches for developing gluten-free bread with particular emphasis on sourdough technology and alternative ingredients.

2. Coeliac disease (CD)

CD, also called gluten enteropathy and coeliac sprue, is one of the most common food induced diseases in humans caused by the intolerance to wheat gluten and similar proteins of barley and rye in genetically susceptible individuals. It is an immune mediated enteropathy causing inflammation in the small intestine and triggered by the ingestion of the storage protein gluten (Shan et al., 2002). In some human,

* Corresponding author.
E-mail addresses: martina.foschia@ucc.ie (M. Foschia), s.horstmann@ucc.ie (S. Horstmann), e.arendt@ucc.ie (E.K. Arendt), e.zannini@ucc.ie (E. Zannini).
[1] These two authors contributed equally to the work.

http://dx.doi.org/10.1016/j.ijfoodmicro.2016.06.014
0168-1605/

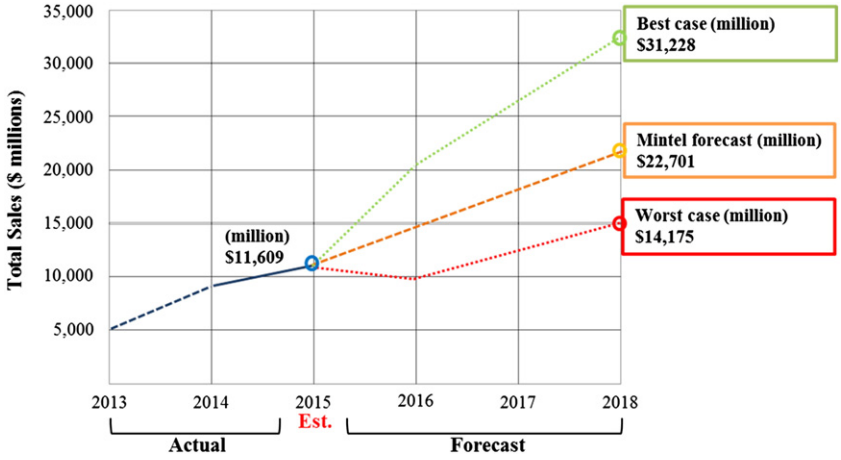

Fig. 1. Sales* and fan chart forecast of gluten-free foods in the US, at current prices, rolling 52 weeks June 2013–June 2018. *Sales through MULO, natural supermarket, and specialty gourmet stores; does not include private label items or sales through Whole Foods Market.
Source: SPINS; Information Resources, Inc./(Mintel, 2015).

leukocyte antigen (HLA), DQ2 and DQ8-positiv individuals lead to a destruction of the villous structure in the small intestine. This is caused by an inflammatory reaction of the small intestine due to the exposure of gluten (Catassi and Fasano, 2011). Recent epidemiological studies verify that 1 in 100 people worldwide suffer from this disorder. Such a high rate makes the CD one of the most widespread food intolerances (Gujral et al., 2012). CD commonly appears in the early childhood, with sore symptoms including chronic diarrhoea and failure to thrive. The symptoms can also develop later in life, when the disease symptoms include diarrhoea, fatigue, and weight loss due to malabsorption and anaemia (Vilppula et al., 2011). CD is a lifelong disease, untreated it is associated with raised morbidity and mortality. Recent research tries to associate CD with coronary heart disease and cerebrovascular disease (Heikkilä et al., 2015). The only treatment of CD is a strict and permanent lifelong adherence to a gluten-free diet. The re-exposure to gluten reactivates the disease, even after many years of avoidance (Koehler et al., 2014).

2.1. Other gluten-related disorders

CD is not the only disease, which is caused by the ingestion of gluten. The intolerances which also fall in the category have the umbrella term "gluten-related disorders" (Sapone et al., 2012). The four main forms besides CD, which are summarized by the umbrella term, are: non-celiac gluten sensitivity, dermatitis herpetiformis, wheat allergy and gluten ataxia (Table 1). Although the only current treatment for these disorders is the avoidance of gluten-containing products, they show different conditions. Based on this reason, it is important to differentiate between the disorders in order to allow more efficient and generalizable advances in the treatment of patients with CD and other gluten-related disorders (Ludvigsson et al., 2013). Recent research focuses also on extra intestinal manifestations of coeliac disease and gathers research of the last three decades (Leffler et al., 2015). An obstacle by the diagnosis of patients suffering from gluten-related disorders is the irritable bowel syndrome (IBS), since its symptoms are similar to those typical for CD and NCGS (non-coeliac gluten sensitivity) such as abdominal pain, gas, bloating and by altered bowel habits (diarrhoea with or without constipation) (Whitehead et al., 1980). Despite these similarities, IBS is triggered by the consumption of the poorly absorbed fermentable oligo-, di-, monosaccharides and polyols (FODMAPs) and insoluble fibre (Lovell and Ford, 2012). However, the restriction of wheat-based products, basically a gluten-free diet, may also lead to reduced fibre intake such as arabinoxylan, which in turn has a positive effect in people with IBS. A review on the recent developments in the pathophysiology of IBS found compelling evidence that genetic factors, diet, the intestinal microbiota and mucosal low-grade inflammation play a major role (El-Salhy, 2015).

Non-coeliac gluten sensitivity (NCGS) is the least clearly defined and researched gluten-related disorder (Lammers et al., 2014). NCGS has been frequently termed "gluten sensitivity" and has been described as

Table 1
Summarizing the prevalence and symptoms of the gluten-related disorders.

Disease	Prevalence in the world (approximate values)	Symptoms	Reference
Coeliac disease (CD)	1%	Chronic diarrhoea, failure to thrive, fatigue, malabsorption, anaemia	Gujral et al. (2012), Vilppula et al. (2011)
Non-coeliac gluten sensitivity (NCGS)	3–6%	Gastrointestinal complaints, weight loss, bloating, diarrhoea, muscular disturbances, bone pain, tiredness, neurological disorders	Cascella et al. (2009), Newnham (2011), Sapone et al. (2012)
Wheat allergy (WA)	0.5–9%	Urticaria, angioedema, erythema, dyspnea, oropharyngeal symptoms, urticaria, angioedema, atopic dermatitis flare, rhinitis, asthma, gastrointestinal symptoms, and anaphylaxis, pruritus, eczema,	Lammers et al. (2014), Matricardi et al. (2008), Morita et al. (2007), Scibilia et al. (2006), Zuidmeer et al. (2008)
Dermatitis-herpetiformis (DH)	0.0001–0.05%	Urticarial plaques, blisters on the elbows, buttocks and knees	Borroni et al. (2013), Caproni et al. (2012), Kárpáti (2015)
Gluten ataxia (GA)	14%	Insidious onset of predominantly gait ataxia, often associated with symptoms and signs suggestive of peripheral neuropathy.	Hadjivassiliou et al. (2013), Hadjivassiliou et al. (2003), Hadjivassiliou et al. (2015), Hadjivassiliou et al. (2008)
Crohn's disease[a]	0.0007–0.0199%	Fever, weight loss, diarrhoea, abdominal pain	Kohn et al. (2010), Lennard-Jones et al. (1997), Loftus et al. (2007), Rizzi (2010), Rubin et al. (2000), Shivananda et al. (1996)
Irritable bowel syndrome[a]	5–30%	Similar to CD and NCGS, bloating, diarrhoea, gas and abdominal pain	Hillilä and Färkkilä (2004), Thompson et al. (2006), Thompson et al. (2000)

[a] Gluten-free diet often recommended but gluten is not the cause for the disease.