Flatbreads: ancient products with a future life

Antonella Pasqualone*
University of Bari "Aldo Moro", Dept. of Soil, Plant, and Food Science (Di.S.S.P.A.),
Food Science and Technology Unit - Via Amendola 165/A - 70126 Bari - Italy
*e-mail: antonella.pasqualone@uniba.it

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SOMMARIO

After a description of the production of flatbreads, with a particular focus on the baking methods, this article reviews the food technology studies on flatbreads over the last ten years. Due to its widespread geographical distribution and high frequency of consumption, flatbread has been considered a suitable carrier for increasing the dietary intake of several microelements and vitamins. Furthermore, the addition of several functional ingredients to flatbread formulation has been widely experimented, mostly of vegetable origin (legume flours and protein isolates, fruit by-products, fenugreek seeds, white mulberry extract, tomato pomace), but also of animal origin, such as whey-based ingredients. Other important research topics regarding flatbreads include quality improvement and shelf life extension, as well as gluten-free formulations.

CLASSIFICATION AND METHODS FOR MAKING FLATBREADS

Flatbreads are very versatile products and can be made from flours of different raw materials. The dough can show different degrees of consistency, can be leavened or not, and can be baked in many different ways, therefore the generic name of "flatbread" includes a multitude of different products, but always showing a reduced thickness, up to a few centimetres (Pasqualone, 2017).

Although some types of flatbreads are produced in South and Central America, the highest diffusion and diversification of flatbreads occurs in the Middle East, North Africa and Central Asia (Pasqualone, 2018).

In **fig. 1** the various types of flatbread are classified according to dough consistency, leavening, layered

Fig. 1 - *Classification of flat breads according to dough consistency, leavening, layered structure, and baking mode.*

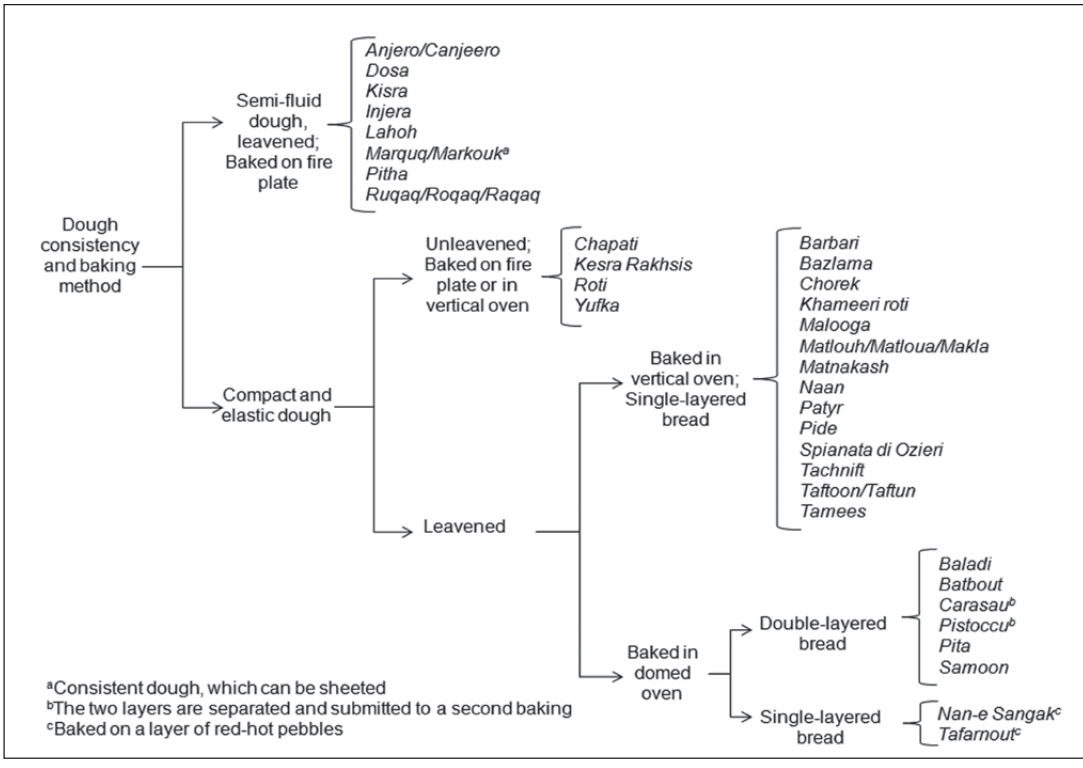

Fig. 2 - *Turkish pide.*

Fig. 3 - *Turkish yufka.*

or non-layered structure of the finished product, and baking mode.

Several types of flatbreads are made by pouring semi-fluid batters onto cooking plates. These batters, often obtained from gluten free cereals or from legumes, such as teff, sorghum, maize, rice, or black beans, are usually fermented. Other flatbreads involve the preparation of a more consistent dough, usually wheat-based, which is rolled before baking. In this case, the dough can be either unleavened, as in the case of the Turkish *yufka* **(fig. 2)**, the Indian *chapatti* and *roti*, and the Lebanese *marquq* bread, or leavened. When leavened, flatbreads can be either very thin or relatively thick. The thicker breads, all classifiable as "single-layer", can be punched to prevent excessive expansion during baking, as is usally done for the Turkish *pide* **(fig. 3)**. Knuckles or metal punches can be used. The latter can also assume a decorative function, as for the Uzbek bread *patyr* **(fig. 4)**, whose tradi-

Fig. 4 - *Uzbek patyr.*

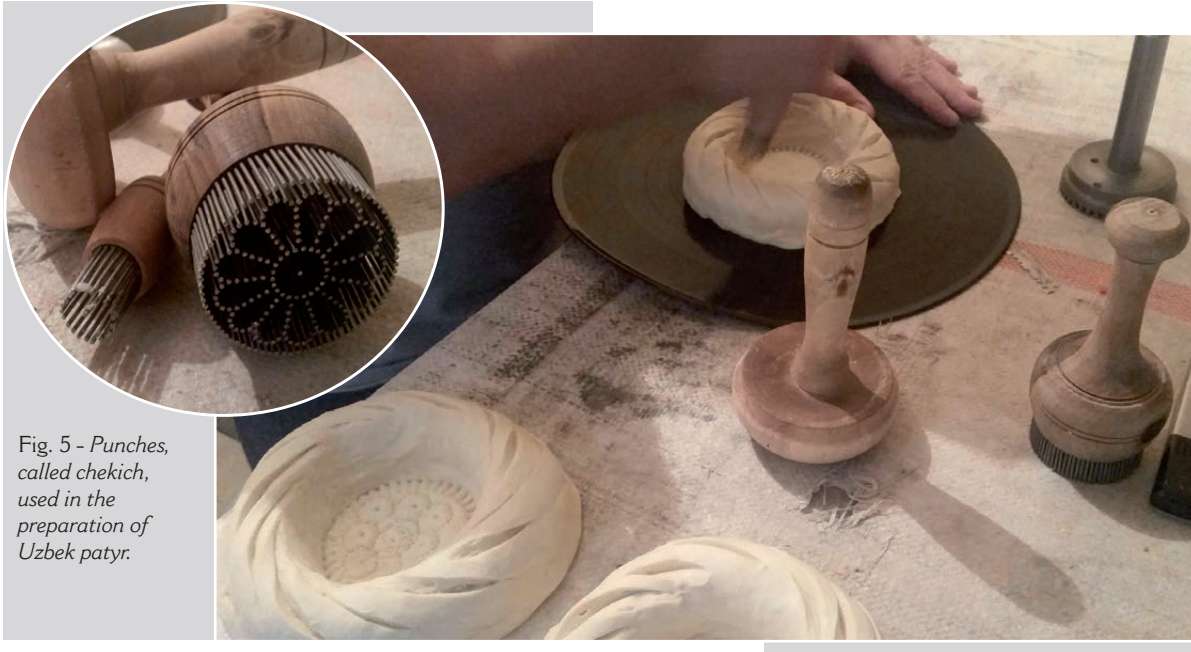

Fig. 5 - *Punches, called chekich, used in the preparation of Uzbek patyr.*

Fig. 6 - *Punching the patyr.*

tional punches are called *chekich* **(figs. 5** and **6)**. When the dough is rolled to a thin layer and is not punched, it will puff during baking **(fig. 7)** and will deflate with successive cooling. Therefore, this kind of flat bread will show an internal cavity or "pocket" and will be characterized by a "double layered" structure. Typical examples of pocket breads are *pita*, the Syrian *khobz* (which simply means "bread" in Arabic) and the Egyptian *baladi* bread (Faridi and Rubenthaler, 1984; Pahwa *et al*., 2016) (**figs. 8** and **9)**.

Fig. 7 - *Dough puffing during the baking step of the Egyptian baladi.*

BAKING FLATBREADS

All flatbreads are cooked very quickly, given the reduced thickness, so their colour remains rather light and the crust is poorly developed. Since ancient times the most simple baking methods for flatbreads have remained almost unchanged over time. For example, flatbreads can be baked on red-hot pebbles, such as

Fig. 8 - *Egyptian baladi*.

Fig. 9 - *Syrian double layered khobz*.

sangak bread **(fig. 10)**, or on convex or flat metal cooking plates, named *tava* or *tawa* in India and Pakistan, *daawo* in Yemen, *saç* in Turkey **(fig. 11)**, and *saj* from Palestine to Syria (Pasqualone, 2017). Another, very particular, baking system typically used for flatbreads is represented by the "vertical ovens", i.e. cylindrical or truncated cone-shaped structures of

Fig. 10 - *Saç ready for baking Turkish yufka*.

Fig. 11 - *Iranian Nan-e Sangak baked on hot pebbles, whose imprint is visible on the surface of the bread*

Fig. 12 - *Tannur on sale in Syria*.

Fig. 13 - *Ignition of the tannur.*

terracotta (Bazzana, 1996; Mulder-Heymans 2002), named *tannur* or *tannour* in Syria, Iraq, Yemen and Saudi Arabia **(fig. 12)**, *tandir* in Turkey and Uzbekistan, and *tandoor* in India, Pakistan and Afghanistan (Pasqualone, 2017).

Traditionally, vertical ovens are wood-burning and have an opening at the top **(fig. 13)**, which replaces the front one in dome ovens. In fact, baking takes place by making the bread, introduced from above, adhere to the inside walls of the oven **(fig. 14)** with the aid of a "bread cushion" or by hand. Of course, flatbread loaves are not very heavy, therefore the adhesion of the loaf to the wall, due to gelatinized starch, is sufficient to keep the bread in the right position, at least while the loaf is moist.

Vertical ovens can be portable, in which case they are simply placed on the ground, or can be fixed **(fig. 15)** (Parker and Uzel, 2007). Large vertical ovens can be placed with a pronounced inclination and therefore appear horizontal, as the Uzbek *tandir* **(fig. 16)**. In this case, the almost horizontal position makes the vertical oven resemble a domed one, but the way

Fig. 14 - *Bread being baked on the inner walls of tannur.*

Fig. 15 - *Tannur in a rural area in Syria*.

Fig. 16 - *Uzbek tandir, placed almost horizontally.*

of using it remains that of the vertical oven. Bread is pressed onto the inner side walls of the oven, up to the vault **(fig. 17)**. Also modern versions of vertical ovens, electric or gas fuelled, are now available. In addition, automatic bread-making lines have been developed for the industrial production of both single and double-layered flatbreads, equipped with tunnel ovens with moving floor.

THE GEOGRAPHICAL DISTRIBUTION OF STUDIES REGARDING FLATBREADS

A systematic search in the scientific database "Web of Science core collection" for articles whose title contains the words "flatbread" results in 189 items published from 2008 to 2017, of which 71 mentioned "flatbread" in the title. The majority of these articles (58%) have been published in the last five years, indicating an increasing interest in traditional products such as flatbreads which, besides being nutritious, are the expression of a local culture.

In the last ten years, Indian flatbreads have been the most studied (14 articles contain "Indian flatbread" in the title), followed by Iranian flatbreads (6 articles). All the other geographical areas contributed with at least one article. However, more in detail, the most

Fig. 17 - *Uzbek patyr being baked on the inner walls of tandir.*

studied has been the Iranian *barbari* bread, with 18 papers mentioning it in the title, followed by another Iranian bread, namely the *sangak* bread (11 articles). Then follows the Indian *chapatti/chapatti* (9 articles), *parotta* (5 articles) and *naan* (4 articles). The Egyptian *baladi* bread and the Armenian and Iranian *lavash* have been considered in 4 articles each. The Ethiopian *injera* is mentioned in the title of a single study.

It is worth noting that, in this framework, very little attention has been given to the Italian flatbreads such as, for example, *carasau* and *piadina*, which in the last ten years, have only been mentioned in one article title each, in spite of the fact that these products represent a strong point for local economy, being consumed in the areas of production and beyond.

RESEARCH TRENDS FOR FLATBREADS

As well as quality definition and improvement, the main research trends regarding flatbreads are related to the nutritional and health aspects, as for all other foods. In particular, according to the Web of Science database, in the last ten years 36% of articles (28 out of 77) contained the words "quality" and "flatbreads" in the title, and 10% of studies mentioned "fortification/fortified" together with "flatbreads" in the title. In addition, 10% focused on "storage" variations of flatbreads and another 10% on the improvement of "shelf life" in flatbreads. The remaining papers focused on antioxidant activity, glycemic index control, gluten-free formulation, and process automation.

SHELF LIFE IMPROVEMENT

The shelf life of flatbreads has been the object of several studies because the social structure of the areas of production has progressively changed from rural to urban, and buying bread everyday has

become less convenient. Similarly to conventional hearth bread, the most used strategies to extend the shelf life of flatbreads have been the use of sourdough and enzymes such as α-amylase (Cevoli *et al.*, 2015; Nanjappa *et al.*, 1999); maltodextrines (Shaikh *et al.*, 2008); polyols (Pourfarzad *et al.*, 2011) acting as plasticizers; emulsifiers such as the monoglycerides (glycerol monostearate and sodium stearoyl lactylate), able to form a complex with helical regions of starch hampering starch retrogradation (Abu-Ghoush *et al.*, 2008a); antimicrobial agents such as fumaric acid, sodium propionate, or mixtures of the two (Abu-Ghoush *et al.*, 2008b); the application of frozen storage (Majzoobi *et al.*, 2011). A very recent study demonstrated that the water-binding ability of aloe vera powder (*Aloe barbadensis* L.), due to the abundant polysaccharides contained in the parenchyma tissue of leaves, is able to retard the staling process of Iranian *barbari* bread (Jafari and Hosseini Ghaboos, 2018).

FORTIFICATION AND FUNCTIONALIZATION

Due to its widespread geographical distribution and high frequency and regularity of consumption, flatbread has been considered a suitable carrier for increasing the dietary intake of several microelements and vitamins. For example, flatbreads have been fortified with iron (Alam *et al.*, 2007; El Guindi *et al.*, 1988) and vitamins D3 and D2 (Tabibian *et al.*, 2017).

The addition of several functional ingredients to flatbread formulation has also been largely experimented. Fenugreek seeds (*Trigonella foenum-graecum* L.), known to have an effect on postprandial blood glucose levels, have been added to flatbread formulation, leading to significant reductions in glycemic response and glycemic index at 10% substitution level (Indrani *et al.*, 2010, 2011; Robert *et al.*,

2016). Lowering the glycemic index has also been the reason for using a newly developed *"atta"* mix (the traditional Indian name for wholemeal flour) (Dubat, 2012) containing bengal gram (*Cicer arietinum* L.), psyllium husk (*Plantago ovata* Forsk), and debittered fenugreek flour (Radhika et al., 2010). Similarly, the addition of chia mucilage (*Salvia hispanica* L.) has been useful in lowering the glycemic index of flatbread, although the results depended on the bread portion (crust showed better results than crumb) (Salgado-Cruz *et al*., 2017).

Fruit by-products, such as apple pomace, papaya peel, and watermelon rinds, opportunely powdered, have been used to prepare hypoglycemic versions of the unleavened Indian flat bread *thepla* (Waghmare and Arya, 2014). Of these, papaya peel powder produced the greatest reduction in the glycemic index. All fruit by-products, however, due to their high water absorption capacity, resulted in an increased dough stickiness, which eventually resulted in an improvement in the texture of *thepla* bread (Waghmare and Arya, 2014). Banana peel powder, a fruit by-product which has been tested by Kurhade *et al*. (2016), increased the softness and pliability in *chapatti* and also contributed several bioactive constituents, such as phenolic and flavonoid compounds.

Dietary fibre from various sources has been added to flatbread formulation due to the known benefits of fibre in reducing the risk of chronic diseases such as diabetes, cardiovascular disease and certain cancers (Jacobs and Gallaher, 2004; Larsson *et al*., 2005; Murtaugh *et al*., 2003). In particular, wheat bran (Başman and Köksel, 2001) and barley fibre-rich fractions (Izydorczyk *et al*., 2008) have been added to flatbread. However, phytic acid, which is the major storage form of phosphorus in cereals, legumes, and oily seeds, is typically found in the outer layers of cereal grains. In order to limit the drawbacks of bran, i.e to improve mineral bioavailability, phytic acid levels

may be decreased by phytase. Mosharraf *et al*. (2009) have, instead, proposed the addition of hydrothermaled wheat bran to *sangak* Iranian flat bread. In fact, the incubation of wheat bran at pH 5.2 and at a temperature of 55 °C for various periods of time can increase the levels of inorganic phosphorus and inositol phosphates lowering the level of phytic acid (Larsson and Sandberg, 1992).

Legumes have been frequently added to flatbread formulation in order to improve the nutritional patterns, especially in terms of proteins, essential amino acid profile, and minerals. In fact, the nutritional quality of wheat proteins is lower than legume proteins because it has low levels of lysine, methionine, and threonine (Kulp, 1988). The addition of either chickpea (*Cicer arietinum*) or pigeon pea (*Cajanus cajan*) flour increased the content of minerals such as phosphorous, zinc, iron and calcium, as well as the protein efficiency ratio of flatbread (Sharma *et al*., 1995). Lupin (*Lupinus albus*), used together with buckwheat and oat flours, significantly increased the protein content without affecting the sensory properties when used at a level of 10% (Levent *et al*., 2012). The interest in lupin is due to the content of proteins and fibre as well as bioactive compounds such as isoflavons and phytosterols (Al Omari *et al*., 2016). Other authors verified that lupin alone, even up to a level of 20%, achieved a nutritional improvement without affecting the physical and sensory properties of flatbread (Al Omari and Abdul-Hussain, 2013). However, the potential benefits of lupin can be limited by the presences of alkaloids, which could confer a bitter taste when incorporated in foods. It was observed that seed germination increases the concentration and activity of phenolic and phytosterol compounds (Rumiyati and Jayasena, 2013) and reduces antinutritional compounds such as phytate, trypsin inhibitors and alkaloids through physiological changes (Mohamed and Rayas-Duarte, 1995). Therefore,

germinated lupin flour has been profitably used in flatbread production (Al Omari *et al*., 2016). Red kidney beans (*Phaseolus vulgaris* L.) have also been added, after being opportunely sprouted for 72 hrs, which did not result in a remarkable increase in protein content but allowed a significant increase of *in vitro* protein digestibility in flatbread (Viswanathan and Ho, 2014).

Soy, peanut and cotton seed flour increased the lysine content (Bhat and Vivian, 1980). Also legume protein isolates have been succesfully used for the same purpose (Tinaysp *et al*., 1985). Kidney bean and black gram (*Vigna mungo*) flours have been proposed by Wani *et al*. (2016) to improve *chapati* formulation, but the colour, taste, aroma, breakability, and overall acceptability decreased significantly at levels of more than 15%. In this regard, a significant effect on the particle size of pulse flour (navy and pinto bean flours) has been observed in the quality of *pita* bread (Borsuk *et al*., 2012).

The addition of amaranth (*Amaranthus tricolor*) leaves to *puris* Indian bread allowed to increase the calcium, iron and β-carotene content (Parimala and Sudha, 2015).

Other more unusual functionalizations have involved the use of white mulberry (*Morus alba* L.), a plant used in traditional Far Eastern medicine. The addition of mulberry extract has been able to increase the antioxidant activity of *paratha* Indian bread (Przeor and Flaczyk, 2016). Tomato pomace powder, instead, contributed relevant amounts of lycopene to *barbari* bread (Majzoobi *et al*., 2011).

A "traditional functionalization" is obtained by sprinkling sesame seeds (*Sesamum indicum* L.) over the surface of flat breads, which is a very common practice. Sesame seeds possess a considerable antioxidant activity, partly due to a high level of phenolic compounds (Chang *et al*., 2002). It has been proven that the incorporation of sesame seeds in bakery products at suitable levels may satisfy the

recommended daily dietary allowances of minerals, because they are rich in calcium, phosphorous, and iron (Alyemeni *et al*., 2011). Similarly, defatted flour of black cumin (*Nigella sativa*), also named black caraway, has been used to increase zinc, potassium, phosphorous, iron, and copper as well as the protein content of flatbread (Osman *et al*., 2014).

Finally, in the category of functional ingredients of animal origin, it is worth mentioning whey-based ingredients, which can be customized to meet specific protein, minerals and lactose compositions. Typically a waste product of the cheese manufacturing process, whey and whey protein products can be used for a wide range of functional and nutritional properties (De Wit, 1998; Ha and Zemel, 2003; McIntosh *et al*., 1998; Morr and Ha, 1993; Smithers, 2008). They can enhance crust browning, crumb structure and flavour, improve toasting qualities and delay staling. Whey proteins have been added to *lavash* (Jooyandeh, 2009), which increased surface brownness, and to *parotta* (Indrani *et al*., 2007), where up to 5% did not affect sensory properties.

FORMULATION OF GLUTEN-FREE FLATBREADS

Several flatbreads are naturally gluten-free because they are made from pseudo cereals or from cereals other than wheat. In particular, *anjero* bread is made using sorghum or maize flour (Kamal-Eldin, 2012), *lahoh* and *kisra* breads are made using sorghum flour (Lyons, 2016; Osman *et al*., 2010), *injera* bread is made using teff flour (Parker *et al*., 1989), *pitha* and *dosa* breads are made from a mixture of local rice flour and black beans **(tab. 1)**. The production process of all these breads involve the preparation of a batter which is poured onto a hot metal disc giving a pancake-like flatbread.

Tabella 1. Denominazioni, area di produzione e tipo di farina impiegata nei pani piatti.

Denominazione	Area di produzione	Tipo di farina
Aeesh Baladi	Egitto	Raffinata o integrale di grano tenero
Anjero/Canjeero	Somalia	Farina di sorgo o di mais
Batbout	Marocco	Semola di grano duro
Bazlama	Turchia	Raffinata di grano tenero
Carasau	Italia	Semolato di grano duro
Chapati	India, Pakistan, Afghanistan	Integrale di grano tenero (*atta*)
Chorek	Turkmenistan	Raffinata di grano tenero
Dosa	India	Farina di riso e di fagioli neri
Injera	Etiopia, Somalia	Farina di teff
Kesra rakhsis	Algeria	Semola di grano duro
Khameeri roti	India, Pakistan	Raffinata di grano tenero
Khobz el dar/Khobz eddar	Marocco, Algeria, Tunisia	Semola di grano duro
Kisra/Kissra/Kisra rhaheefa	Sudan	Farina di sorgo
Lahoh	Yemen, Somalia	Farina di sorgo
Lavash	Armenia, Georgia, Iran, Turchia, Azerbaijan, India, Pakistan	Raffinata di grano tenero
Lepeshka	Uzbekistan, Kazakistan	Raffinata di grano tenero
Malooga	Yemen	Raffinata di grano tenero
Marquq/Markouk	Libano	Raffinata di grano tenero
Matlouh/Matloua/Makla	Algeria, Marocco, Tunisia	Semola di grano duro
Matnakash	Armenia	Raffinata di grano tenero
Naan	India, Pakistan	Raffinata di grano tenero
Nan-e Barbari	Iran	Raffinata di grano tenero
Patyr	Uzbekistan, Kazakistan	Raffinata di grano tenero
Pide	Turchia	Raffinata di grano tenero
Pistoccu	Italia	Semola di grano duro
Pita	Grecia	Raffinata di grano tenero
Pitha	India	Farina di riso e di fagioli neri
Roti	India, Pakistan	Raffinata di grano tenero
Ruqaq/Roqaq/Raqaq/Rogag	Arabia Saudita, Emirati Arabi Uniti, Iraq settentrionale, Egitto	Integrale di grano tenero
Samoon	Iraq	Raffinata di grano tenero
Spianata di Ozieri/Spianata sarda	Italia	Semola di grano duro
Nan-e Sangak	Iran	Raffinata o integrale di grano tenero
Tachnift	Marocco	Semola di grano duro
Taftoon/Taftan	Iran	Raffinata o integrale di grano tenero
Tamees	Afghanistan, Arabia Saudita	Raffinata di grano tenero
Yufka	Turchia	Raffinata di grano tenero

In addition, for those flatbreads which are usually wheat-based, and whose production process requires the preparation of a consistent and elastic dough, gluten-free versions have been created by adding hydrocolloids, such as xanthan gum, guar gum and carboxymethylcellulose (Pahwa *et al*., 2016), to mimic the viscoelastic properties of gluten. Hydrocolloids provide a range of functional properties which make them suitable to improve texture and control moisture loss during storage.

CONCLUSIONS

Traditional foods reflect cultural inheritance and have influenced contemporary dietary patterns. Bread is an ancient product, but it is modern at the same time. In fact, it can be considered the most widespread ready-to-eat food.

Social changes, occurring also in developing countries, where flat breads are largely consumed, have a significant impact on the development of the so-called lifestyle diseases. Therefore, food companies can profit from the increasing demand for traditional foods, but at the same time have to increase their nutritional and healthy features in order to fulfil the requirements of modern consumers.

Flatbread is a suitable carrier for an array of bioactive functionalizing compounds. Several functional ingredients have been experimented in flatbread formulation, mostly of vegetable origin (legume flours and protein isolates, fruit by-products, fenugreek seeds, white mulberry extract, tomato pomace), but also of animal origin, such as whey-based ingredients. These functionalizations have allowed flatbreads to become increasingly popular, also outside the traditional areas of production. Quality improvement and shelf life extension, as well as gluten-free formulations, have been other important research topics regarding flatbreads.

Regarding the geographical distribution of the research, however, it emerges that little attention has been given to the Italian flatbreads, in spite of the fact that these products represent a strong point for the local economy, being consumed in the areas of production and beyond. Greater research should be carried out to define quality and improve Italian flat breads, keeping traditions alive but without excluding innovation.

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