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Review article

THE EFFECT OF BASIC RAW MATERIALS IN THE PROCESS OF WHEAT DOUGH FREEZING*

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ABSTRACT: This paper represents an overview of the application and effect of basic raw materials (wheat flour, yeast, salt and water) in frozen wheat dough manufacturing. Wheat flour quality requirements are defined with the aim of obtaining frozen wheat dough of optimal quality. Wheat flour applied in frozen dough manufacturing should be of a tailor-made quality with high level of quality proteins (protein content min. 12% / s.m.; sedimentation value min. 35; energy according to extensograph min. 70Ej and wet gluten content min. 30%). Here is also reviewed the possibility of widening the assortment of frozen dough products by the application of nutritively valuable raw materials, like spelt wheat flour. Some spelt wheat varieties in their biochemical and rheological parameters meet the criteria for the application in frozen dough manufacturing. The substitution of wheat flour by spelt flour in the quantity even up to 60% is most commonly performed. In order to achieve the optimal quality of frozen yeasted wheat dough, the applied baker's yeast has to be of certain physical characteristics, such as: high level of cryoresistance, high level of trehalose, small share of bud cells, and high speed of adaptation to various substrates. Water is cast an important role in the process of forming and developing of ice crystals during freezing and storage of frozen wheat dough. By the application of tailor-made quality raw materials, adequate raw material composition and defined technological parameters (freezing velocity and storing temperature), the negative influence of ice crystals on frozen wheat dough quality can be decreased.

Key words: *freezing, wheat dough, wheat flour, spelt flour, yeast, salt, water*

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INTRODUCTION

Freezing technology in bread-making industry is used to preserve dough pieces, partially baked, semi-products and end-use bakery and confectionery products (Prence et al., 1956).

The advantages (Baier-Schenk, 2005) of the application of freezing technology and new technologies in creating competitive advantage (Milovanović, 2010) are the following:

- The possibility of optimal work organization (no need for night shifts);
- Use of equipment is more costeffective;
- The possibility of manufacturing fresh products around- the-clock;
- Achieving optimal harmonization of manufacturing and selling capacity;
- Facilitated distribution (once a week delivery);

- Increased income due to a more economical organization.

The manufacturing and selling of frozen food has been significantly expanding over recent years due to opening of large shopping malls, restaurant chains and bakery goods boutiques. The greatest increase of selling was realized by frozen pizza, as well as other frozen semi-baked products (semi-baked bread, bakery goods, cakes), which final baking is realized in the household (Katalenić, 2006).

Lately, the production of frozen doughs, bakery semi-products and products is following the trend of healthy food by widening the assortment with nutritively more valuable products. One of the criteria in the selection of raw materials for such products manufacturing is their functionnality (Mišan, 2010; Šarić et. al., 2009) or breeding under ecological conditions, as well as the harmonization of their quality with technological quality and the quality of final product. There is a great interest for the application of spelt wheat flour (*Triticum aestivum ssp. Spelta*) in both conventional bread-making manufacturing (Bodroža-Solarov et al., 2009; 2011) and in manufacturing of frozen wheat dough products (Kozlowicz & Kluza, 2008) due to its agronomic (high resistance to pests and capacity to grow in soil with limited fertility in humid and cooler conditions), nutritive (higher mineral concentration (Fe, Zn, Cu, Mg and P), lower content of phytic acid in comparison to common wheat (*Triticum aestivum ssp. Vulgare*) and therapeutic capacities (lower glycemic index values, high level of resistant starch and antioxidative activity) (Hoseney, 1994; Marconi et al., 2002; Kohajdová & Karovičová, 2008; Ruibal-Mendieta et al., 2005; Fulcher et al., 2002; Lopez et al., 2002; Zienlinski et al., 2008 a,b).

Taking into account high protein and ash contents, spelt wheat flour is possible to be used for manufacturing special bakery products in order to improve their taste and freshness (Galova & Knoblochova, 2000). Spelt wheat and its products are rich in dietary fibres, and bread with spelt was proved to contain fructans that are classified into fibres and are well-known for their probiotic effects. Spelt flour also possesses higher content of oligofructose than wheat flour (Marques et al., 2007).

During wheat dough freezing there occur some physical and chemical changes (Pence et al., 1956) that influence the decrease of baker's yeast activity and reduction of dough resistance, which results in decreased gas power retention (CO_2), prolonged duration of final fermentation and decreased volume of final product (Brummer & Morgenstern, 1990).

Minimization of negative influence of freezing on frozen dough quality and its resulting product can be achieved by both selection of raw materials of adequate quality and optimization of dough composition, as well as the application of adequate manufacturing conditions (Schiraldi et al., 1996). This paper presents an overview of influence of basic raw materials from the aspect of quality and quantity criteria on frozen wheat dough quality.

Flour

For the manufacturing of frozen wheat dough, it is applied wheat flour of tailor-made quality with high quality proteins content (protein content min. 12% /d.m, sedimentation value min. 35), wet gluten (content min. 30%) and high energy value according to extensograph (min. 70 B.U.). Tailor-made quality of flour for frozen doughs provides great gas power retention during thawing and final fermentation (Marston, 1978; Benjamin et al., 1985; Sideleau, 1987; Kulp et al.,1995; Bhattacharaya et al., 2003; Torbica et al., 2008). The best results are achieved with flour from selected wheat varieties or by preparation of adequate mixtures (Gelinas et al., 1996; Perron et al., 1998; Lu et al., 1999b; Boehm et al., 2004; Živančev et. al., 2009).

When selecting adequate flour, protein quality and gluten power are more important than total protein quality (Inoue et al., 1992; Lu et al., 1999; Mastilović et. al., 2008). Analyzing the effect of certain gluten fractions (glutenin and gliadin) of flour obtained from two qualitatively different wheat varieties (strong and weak) on the quality of bakery goods manufactured from frozen dough, Lu et al. (1999) concluded that the origin of glutenin has a more important effect on frozen dough product volume than the origin of gliadin. Besides, it is recommended that flours applied for frozen dough manufacturing have less damaged starch (max. 5% for soft wheat), lower amilolytic activity (minimal falling number 300s) and the absence of protease enzyme activity (Marston, 1978; Räsäen, 1998; Brümmer, 2001).

Characteristics of gluten proteins in *Triticum aestivum ssp. Spelta* define baking dough properties during manufacturing and freezing, which is further reflected upon product quality.

The increased share of gliadin fraction in some spelt wheat varieties decreases gluten elasticity, resulting in softer doughs after thawing which has a negative effect upon stability in final fermentation, as well as product volume (Kuhn et al., 2002).

The composition of protein fraction in spelt wheat is conditioned by its variety classifycation. Some spelt wheat varieties (Baulander Spelz, Schwabenkorn, Holsternkorn, Franckenkorn) have optimal values of Gli/Glu relation (1,21) and value 8 for Glu-score which exhibits good quality of the variety regarding flour baking properties (Galova & Knoblochova, 2000).

Rheological quality of dough made of some spelt wheat varieties (Nirvana) is at the level of some common wheat bread varieties (Edevan) (Bodroža-Solarov et al., 2011).

Contrary to protein and wet gluten content which is higher in spelt wheat varieties (Bodroža-Solarov et al., 2009), starch content is at similar level (around 62%), but the share of resistant starch is different (Kohajdova & Karovičova, 2008; Galterio et al., 2003).

Flour made of wholegrain spelt wheat (*Triticum aestivum ssp. Spelta*), dough and dough products exhibited remarkably high level of resistant starch in comparison with common wheat (*Triticum aestivum ssp. Vulgare*) (Abdel-Aal & Rabalski, 2008).

The above quoted facts show that flour of some spelt wheat varieties represents a good potential for frozen dough manufacturing. The substitution of 60% of wheat flour by spelt flour and the addition of sorbitol as replacement for sucrose contributes to the increase of frozen dough yield and reduces loss at baking in relation to dough with sucrose and without spelt flour as an ingredient (Kozlowicz & Kluza, 2008).

However, with the increasing of spelt flour and sorbitol share, the volume and value number of product quality decreases. Taking into account sensory quality, volume and yield of frozen dough products, the best result is achieved by substitution of wheat flour in the quantity from 20% to 40% with spelt wheat flour in its raw material composition. Product made of frozen dough with spelt flour is characterized by its regular shape with porous crumb of a very good elasticity, pleasant taste and smell (Kozlowicz & Kluza, 2008).

Yeast

Yeast is an essential component for gas production in dough, i.e. dough proofing, as well as for obtaining of product with optimal volume and adequately developed crumb. Selected varieties of *Saccharomyces cerevisiae* are most commonly applied in bread-making industry. *Saccharomyces cerevisiae* is a baker's yeast used for manufacturing of bread, bakery goods, special bakery products and frozen dough (Pejin et al., 2005).

Fermentative activity of baker's yeast expresses its capacity to develop gas (CO_2) in dough and lead to the increase of dough volume, i.e. product crumb development. The most favourable temperature for reproduction and yeast development ranges from 25 °C to 26 °C, and for dough fermentation is 30-32 °C. Besides, yeast improves bakery goods nutritive value, regarding the fact that it contains B-complex vitamins, proteins and minerals. Commercial baker's yeast (*Saccharomyces cerevisiae*) reduced production of AFB1 (aflatoxin B1) by all investigated isolates of *Aspergillus flavus*. Since the higher concentration of *S. cerevisiae* cell suspension showed stronger effect on reduction of AFB1 content, it can be concluded that AFB1 reduction depend on concentration of baker's yeast

(Šarić et. al., 2008). Wheat flour quality influences fermentative yeast activity. Researches proved that the flours which provide good quality of frozen dough products do not necessarily represent the best ones for baker's yeast fermentative activity (Bruinsma & Giesenschlag, 1984; Pejin et al., 2005).

When we assess fermentative yeast activity in frozen doughs, we also take into account the composition and structure of dough, particularly gluten structure. The process of dough thawing influences both yeast cells and gluten matrix. Therefore, the quality of frozen yeasted wheat dough is influenced by two factors: 1) CO_2 quantity conditioned by fermentative yeast activity and 2) strength of dough to retain CO_2 (CO_2 retention). It is confirmed that freezing influences the decrease of fermentative yeast activity, but also the technique of preparation of dough for freezing and finalization (thawing) (Pejin et al., 2005).

The most important factor for preserving yeast viability in frozen dough is the inverse relationship between yeast activation before freezing and yeast stability in frozen dough (Meritt, 1960; Kline & Sugihara, 1968; Tanaka et al., 1976; Hsu et al., 1979a; Hino et al., 1987; Holmes & Hoseney, 1987; Hino et al., 1990). The decrease of yeast viability can be caused either by ice crystals that physically damage the external membrane of yeast cells or aggregation of their metabolites that cause autolysis of cells (Kline & Sugihara, 1968; Hsu et al., 1979b, Stauffer, 1993).

One of the negative consequences of freezing process is the prolonged time of final fermentation of thawed yeasted dough. Wolt & D'Appolonia (1984) established that thawed yeasted dough pieces (stored in frozen state up to two weeks) with active dry yeast and instant active yeast take shorter time to reach full fermentation in relation to dough pieces made of fresh compressed yeast. However, in prolonged storage (over two weeks), thawed dough pieces with fresh compressed yeast took shorter time to reach full fermentation in relation to dough pieces with instant active yeast and active dry yeast. The authors (Wolt & D'Appolonia, 1984) hold the opinion that glutathione secreted from yeast cell does not have an effect upon the time of final fermentation of thawed dough pieces, but that the crucial role is cast to fermentative activity of the applied yeast type. The type of the applied baker's yeast also has an effect upon quality of frozen yeasted dough products (Filipović & Kaluđerski, 2000). The presented results are in favour of the fact that fresh compressed yeast can also be successfully applied in frozen dough manufacturing; however, it has to be taken into account that fresh compressed yeast in frozen dough can lose up to 50% of its initial activity during 12 weeks of storage (Bruinsma & Giesenschlag, 1984; Ribotta et al., 2003; Dodić et al., 2007). Fresh compressed yeast is sufficiently resistant to freezing; however, its resistance to freezing decreases in dough system, due to unfavourable environment (osmotic and oncotic pressure) and in an unfavourable physiological phase (fermentatively active to a certain degree), therefore, it is frequently applied for frozen doughs that are stored within shorter period of time (from two to four weeks) (Casey & Foy, 1995; Dodić et al., 2007). One of the ways of overcoming of negative effects of freezing upon cell viability of fresh compressed yeast in frozen dough is the application of greater quantity (for about 50%) in relation to quantity for fresh dough preparation, in order to compensate for the decrease of fermentative yeast activity during storage in frozen state (Meritt, 1960; Drake, 1970; Javes, 1971; Lorenz, 1974; Marston, 1978).

In order to obtain optimal results of fermentative activity in frozen yeasted doughs, baker's yeast must possess defined physical characteristic (Pejin et al., 2005), like the following:

- Natural cryoresistance for which Aquaporine genes AQY1 and AQY2 are responsible;
- High glycolytic activity (velocity of glucose decomposing) and high velocity of adaptation to various substrates;

- High stability conditioned by trehalose content (trehalose concentration min. 10%), and
- Bud cells share of maximally 5%.

Researches indicate that there are possibilities for improving fermentative yeast capacity in frozen dough. One of the possibilities is the application of physical treatment that induces tolerance of fresh baker's yeast in frozen dough system. Phimolsiripol et al. (2008) showed that the effect of their cool treatment of dough at temperatures of 0 °C and 10 °C prior to processing and freezing increases fermentative yeast activity which results in improving of frozen yeasted dough quality for the storage period of 17 days.

Sahara et al. (2002) found proofs that cold-induced states are connected with changes in the direction of improving yeast cryoresistance in frozen dough system. The explanation given by Kaul et al. (1992) claims that cold pre-treatment causes delayed fluidity of yeast cell membrane, which is in fact protective factor of the very cells. Besides, cold pre-treatment enables better water absorption by starch and protein, so that the amount of unabsorbed water in dough is decreased, resulting in less water around the yeast that can be frozen and form ice crystals, which also leads to smaller damage during freezing and storage in frozen state (Phimolsiripol et al., 2008).

Another possibility of the improving of fermentative yeast activity in frozen dough is the application of specific protective agents that are capable of penetrating the cell membrane. An efficient agent for yeast cell protection in freezing process is glycerol. The addition of glycerol in the amount of 1% to 20% to fresh yeast (with 27-28% of dry material) fully protects yeast cells, rendering them resistant even in repeated freezing-thawing cycles (Pejin et al., 2005).

The aim of yeast producers is isolation of cryoresistant yeast strains and their application in frozen dough manufacturing. Oda et al. (1986) selected 11 cryoresistant strains out of over 300 *Saccharomyces* species. Teunissen et al. (2002) used over 200 freezing-thawing cycles of dough in order to isolate cryoresistant yeast strains.

Different species of *Saccharomyces cerevisiae* in dough system exhibit different levels of cryoresistance (Oda et al., 1986; Manzoni et al.,1995) that originate from:

- Content and structure of lipids that are present in the composition of yeast cell cytoplasm. The content and structure of lipids influence the fluidity of plasmatic membrane, and fluidity defines the tolerance of yeast to freezing in yeast dough (Gelinas et al., 1993**;** Murakami et al., 1994);

- Content of intra-cell proline and content of intra-cell electrified amino acids. Intra-cell proline has cryoprotective properties in *Saccharomyces cerevisiae*, and also plays a protective role in oxidative stress (Terao et al., 2003; Morita et al., 2003) of naturally present endogenous trehalose which acts as cryoprotector for the yeast cells of *Saccharomyces cerevisiae* (Gelinas et al., 1985; Hino et al., 1990; Shima et al., 1999; Shima, 2000). The same effect is present in added trehalose (Hirasawa et al., 2001; Salas-Mellado & Chang, 2003). In order to avoid the damage of fresh compressed yeast by dough freezing, it is necessary the presence of 4-5% trehalose (Meric et al., 1995).

For frozen yeast dough manufacturing tailor-made yeast strains are used, resistant to low temperatures. Tailor-made yeast strains should be osmotolerant and highly resistant to freezing (Casey & Foy, 1995). According to literature data, those are strains that have about ten or more percenttage higher, or, perhaps, lower protein content in dry material in comparison to common strains and also with high trehalose content (Filipović & Kaluđerski, 2000).

Hsu et al. (1979b) hold the opinion that yeast containing >57% of protein has a good fermentative activity immediately after thawing.

The group of cryoresistant yeasts also contain some selected strains of *Saccharomyces* genus, namely *Saccharomyces* *fructum* (Versele et al., 2004) and *Torulaspora delbrüeckii* (Baguena et al., 1991; Murakami et al., 1994; Yokoigawa et al., 1995; Almeida and Pais, 1996).

However, it is inevitable a certain decrease of fermentative yeast activity during freezing and storage in frozen state, even in conditions of controlled temperature, rapid processing and usage of tailor-made yeasts tolerant to freezing (Autio et al., 1992; Stecchini et al., 2002). Nevertheless, the application of yeasts tolerant to freezing helps improvement the frozen dough quality and enables prolonged fermentation prior to freezing in prefermented doughs manufacturing (Takano et al., 2002a).

Salt

Salt is an obligatory ingredient of a bakery product that contributes to its taste. Salt also has a functional effect in bakery goods manufacturing because it contributes to gluten strengthening and controls fermentation, therefore also controls bread volume. Due to the mentioned properties, it is of essential importance the adequate salt dosage in manufacturing dough for freezing. An optimal salt quantity in dough mixture adds to amylase activity (contributes to maltose production - food for yeast) and inhibition of flour protease (Giannou et al., 2003).

Inadequate quantity of salt in dough has the consequence either excessive or insufficient fermentative yeast activity, impairrment of physical dough properties and unfavourable volume and texture of the product. Recommended dosage for frozen wheat doughs ranges from 1.75% to 2.25% per flour quantity (Kozlowicz & Kluza, 2008).

In frozen yeasted dough salt represents an ingredient that decelerates fermentative yeast activity and prolongs fermentation time (Jinhee, 2008).

It is recommended a delayed dosage of salt in dough mixture (five minutes after the beginning of mixing) for freezing, because gluten development is faster in the absence of salt, leading to shortening of mixing time (up to 25%), which also provides lower dough temperature (El-Hady et al., 1996).

Water

When freezing dough, water fully or partially turns into ice due to heat dissipation in lowering the temperature below freezing point. Turning water into ice also causes complex physical and physico-chemical changes that can cause impairment of quality, particularly if the method of preparation and freezing is not adequate or if storing conditions in frozen state are not optimal (Bebić, 1974).

Lowering of dough temperature requires heat dissipation known as “noticeable”. For changing physical state of water in dough from liquid into solid, it is necessary significantly higher heat dissipation known as “latent” without temperature change (Vujić, 1983).

On intensive heat dissipation the temperature at dough surface is equally lowering, while inside the dough, due to water freezing, temperature fall is much slower. When the greatest amount of water in the center of dough piece is turned into ice, the process of temperature lowering is accelerating. In the center of dough piece the temperature remains constant for some time, until the moment of reaching freezing point in the conditions when the cooling is finished, and water freezing has not started yet (Kremić, 1989).

During freezing, the distinction line between frozen and non-frozen part moves from the surface towards the center of dough piece. When the distinction line reaches the center and starts forming ice in it, then the internal interchange of heat and equalization of temperature in the whole dough piece become more rapid, due to the fact that its temperature conductivity is increased, and temperature emission from the surface is minimal (Kremić, 1989).

Ice-forming represents the most important water transformation during dough freezing.

Calorimetric (DSC) measurements of frozen dough showed that under practical conditions about 53% of total water content turns into ice (Baier-Schenk, 2005). A part of water present in frozen dough is not crystallized during storage, because the relevant phase becomes too much viscous in order to enable the nucleation and growth of solid phase. In fact, this is the result of concentration process by freezing. The process causes tensions inside dough structure that can not lower if the freezing process is rapid enough. The details of this mechanism in multicomponent and multiphase system like dough are mostly not cleared yet (Cauvain, 2003).

During storage in frozen state, the size of ice crystal enlarges and after six months the crystals reach almost 500 μm.

Ice crystal growth during storage of dough in frozen state depends on the amount of non-absorbed water (so-called “free” water), therefore it is necessary that the amount of free water in dough that is to be frozen is reduced to minimum, by reducing the total amount of water added into the mixture. Räsänen, (1998) in his experiments also came to the conclusion that the reduced water amount in prefermented dough for 2% in relation to the amount of water in fresh dough (consistency of 500 B.U.) improves the stability of prefermented frozen dough during its storage.

The phenomenon of ice crystal growth (ice re-crystallization) in dough pores is also inhibited by high freezing velocities (above 5cm/h).

It is well-known that molecule spreading is mostly restricted if the system temperature is lower than “glass transition” temperature (Tg’). “Glass transition” temperature comprises temperature area where system viscosity is maximal and no further molecule transfer from liquid into solid phase is possible, i.e. no further ice crystal growth is present (Cauvain, 2003).

Any of the methods that can lead to diminishing of ice re-crystallization (ice crystal growth) in dough, like, for example, rapid freezing (above 5cm/h) and/or storage below dough Tg’ temperature (“glass transition” dough temperature, which is -13 °C) improves baking properties of frozen dough (Baier-Schenk, 2005).

CONCLUSION

Cooling technology in bread-making industry is applied for preserving dough pieces, partially baked and baked bakery products.

Freezing technology benefits to bread-making industry due to the following possibilities: more efficient work organization, more cost-effective equipment usage, standardized product quality, optimal harmonization of manufacturing and selling organization and facilitated distribution.

Contemporary trend of manufacturing and consummation of healthy and functional food has also been conducting in manufacturing of frozen doughs, bakery semi-products and products by the application of traditional and/or nutritively valuable raw materials like spelt wheat flour (*Triticum aestivum ssp. Spelta*). Flours obtained by certain spelt wheat varieties exhibit good baking potential and offer possibility to be applied in frozen wheat dough manufacturing.

The process of yeasted dough freezing causes changes in the structure of gluten and yeast cells, whose consequence is decreased gas power retention, gas production, prolonged time of final fermentation and decreased specific product volume.

By the application of adequate (tailor-made) quality of basic raw materials and harmonization of technological process, it is possible to decrease the negative effects of freezing and storage in frozen state to viability of yeast cells and structure of frozen dough.

Investigations to come should be directed to registering cryoresistant yeast strains, defining of raw material composition of dough and freezing conditions with acessory equipment that will benefit to prolonging of frozen dough storage time, shortening the time necessary for finalization and achieving optimal quality of frozen dough products.

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УЛОГА ОСНОВНИХ СИРОВИНА У ПРОЦЕСУ ЗАМРЗАВАЊА ПШЕНИЧНОГ ТЕСТА

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Сажетак: У раду је дат преглед примене и улоге основних сировина (пшенично брашно, квасац, со и вода) у производњи замрзнутог пшеничног теста. Дефинисани су захтеви квалитета пшеничног брашна и пекарског квасца у циљу добијања замрзнутог пшеничног теста оптималног квалитета. Пшенично брашно примењено у производњи замрзнутог теста треба да буде наменског квалитета са високим садржајем квалитетних протеина (садржај протеина мин. 12%/с.м.; седиментациона вредност мин. 35; енергија по екстензографу мин. 70 Еј и садржај влажног глутена мин. 30%).

Дат је осврт на могућност проширења асортимана производа од замрзнутог теста применом нутритивно вредних сировина, као што је брашно од спелта пшенице. Поједине сорте спелта пшенице по својим биохемијским и реолошким показатељима задовољавају критеријуме за примену у производњи замрзнутог теста. Најчешће се врши супституција пшеничног брашна са спелтиним брашном у количини и до 60%. Да би се постигао оптимални квалитет замрзнутог квасног пшеничног теста примењени пекарски квасац мора поседовати одређене физичке особине, као што су: висок степен криорезистентности, висок садржај трехалозе, мали удео ћелије са пуповима и велику брзину прилагођавања различитим супстратима. Вода има значајну улогу у процесу стварања и раста кристала леда током замрзавања и складиштења замрзнутог пшеничног теста. Применом сировина наменског квалитета, одговарајућим сировинским саставом и одређеним технолошким параметрима (брзина замрзавања и темепратура складиштења) могу се смањити негативни утицаји кристала леда на пад квалитета замрзнутог пшеничног теста.

Кључне речи: *замрзавање теста, пшенично брашно, брашно од спелте, квасац, со, вода*

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