Technological and sensorial role of yeast β -glucan in meat batter reformulations

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Abstract This study shows that apart from acting as nutritional value improver, yeast β -glucan can be successfully used to reformulate meat products. When added to meat batters, yeast derived ingredients containing β -glucans (GOLDCELL[®] IY B and GOLDCELL[®] BETA GLUCAN) improved the emulsifying capacity (up to 5 increments), the water holding capacity (up to 8 increments) as well as the emulsion stability. A decrease in total fluid release up to 4.30% and 3.99%, respectively with GOLDCELL[®] IY B and GOLDCELL[®] BETA GLUCAN respectively, at 1.5% addition level was observed. A significant decrease in hardness and fracturability values was also observed, while maintaining the structural cohesiveness of the samples, in part due to the increase in humidity content. A maximum level of 3% ingredient mixture can be added to meat batter formulations without significant impact on sensory characteristics. Adding yeast β -glucan to meat batters can allow food to decrease the NaCl and polyphosphate content in meat products.

Keywords GOLDCELL[®] · Emulsion · Water holding · Hardness · Fracturability · Cohesiveness

Introduction

Due to their high caloric content and pleasant sensory attributes, finely comminuted meat products (e.g. frankfurters, bolognas, hotdogs, Polish sausages) score high in consumer acceptability. In order to obtain a high quality comminuted product, the meat batter needs maximum stability. This can be achieved by decreasing the particle size during emulsion formation, providing enough protein extract to coat the fat particles, and by adding specific stabilizers. Commonly used stabilizers in the meat industry are represented by vegetal and milk derived proteins and other hydrocolloids. Since consumer demand is focusing now on health oriented products, food industry started a process of reformulation. As meat products are known to have high amounts of salt and saturated fats (Jiménez-Colmenero et al. 2001), food technologists turn to new ingredients to reformulate such products. Studies show that dietary fibres can be used to improve the technological and sensory characteristics of reformulated meat products (Kim et al. 2015; Schmiele et al. 2015; Zhuang et al. 2016).

From a technological point of view, the addition of cereal β -glucans to food matrices has been proven beneficial by modifying the textural properties and improving stability of emulsions during storage (Santipanichwong and Supphantharika 2009), based mainly on their ability to increase the viscosity of aqueous solutions and to form stable gels. Beta-glucan is a good fat mimic in mayonnaise (Sevier et al. 2006) and fat replacer in breakfast sausages (Morin et al. 2002). Oats β -glucan is considered a good partial substitution alternative for salt, after successfully

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being used to formulate low salt chicken breast meat gels of similar hardness to that of full NaCl samples (Omana et al. 2011). This behaviour is explained by the absorption of large amounts of water and the formation of dense matrices that play a key role in textural parameters enhancement of reduced salt and reduced fat formulations (Álvarez and Barbut 2013).

While cereal β -glucan has been extensively studied and added to diverse food formulations such as cereals, pastas, noodles, baked goods as well as dairy and meat products (Hatcher et al. 2005; Morin et al. 2004, 2002; Oste 2002), yeast β -glucan impact over food reformulation is still under review.

The perspective of adding yeast β -glucans to food formulations has been researched by few authors with several application including cookies, bread, yoghurt, fruit juices and meat (Naumann et al. 2006; Piotrowska et al. 2009; Thammakiti et al. 2004).

The potential contribution to health of β -glucans has been extensively studied. Beta-glucans from cereal and microorganism sources have been proven to have certain beneficial health implications, from important immune modulation function in vertebrates, when administrated parenterally (Raa 2000; Rodríguez et al. 2009; Zhang et al. 2009), antimicrobial activity against *E. coli*, *B. subtilis*, *S. aureus* and other pathogens (Kaiser and Kernodle 1998; Liang et al. 1998; Shin et al. 2005), to chemo-protective (Hashimoto et al. 2002; Okamoto et al. 2004) and immune function modulation, when administered enterally (Davis et al. 2004).

EFSA releases on April 8th, 2011, the “Scientific opinion on the safety of yeast β -glucans as a novel food ingredient” in which it stated that yeast β -glucans are safe, under the proposed conditions of use. This was followed by the implementing decision (November 24th, 2011) which authorizes the placement on the market of yeast β -glucan as a novel food ingredient (2011/762/EU).

The aim of this study was to investigate the perspective of adding yeast derived ingredients with high content of β -glucan, as a reformulation ingredient, to finely comminuted meat products, by evaluating the technological and sensory impact on cooked meat batters.

Materials and methods

Materials

Pork meat was bought from a local retailer, while salt (NaCl), polyphosphates, sodium nitrate and soy isolate were bought from SUPREMIA Grup (Bucharest, Romania). The two yeast derived ingredients used in this study consisted of an inactive dry yeast powder GOLDCELL®

IY B (G.IYB) and a dietary fibre from yeast cell walls GOLDCELL® BETA GLUCAN (G.BG), both kindly supplied by Biorigin® (São Paulo, Brazil).

Chemical analysis

The chemical and biochemical content of each yeast derived powder was evaluated before starting the experiments. Total nitrogen, fat, ash, moisture and acid detergent fiber was determined by approved methods of AOAC (2016) were determined according to the official methods approved by the Association of Official Analytical Chemists (AOAC). Crude protein content has been calculated using a factor of 6.25.

Water holding capacity

Water holding capacity of the studied ingredients was measured in a meat model system similar to the methodology described by Shahidi & Synowiecki (1997) and by employing the centrifuge test. In order to reproduce the usual meat formulations, the meat model system was made of 70 g of pork meat, 15 g of pork back fat and 15 g of chilled distilled water. Given that the average salt and polyphosphate content used in the manufacture of Romanian emulsion type meat products is of 1.8–2% (w/w) and 0.5% (w/w) respectively, we have designed our experiments with lower content of salts (1.5–1% w/w for salt and 0.3–0.2% w/w for polyphosphates) thus establishing reformulating conditions in regard to those ingredients.

Both yeast derived ingredients were tested at concentrations of 0.5, 1 and 1.5% (w/w). The components were mixed thoroughly using an 800 W Gorenje mixer until emulsion was formed, usually no more than 3 min, with final temperatures not exceeding 15 °C. A control without any added glucan ingredient was prepared. Mixtures were then allowed to rest at 4 °C for an hour before being transferred into vacuum bags, vacuumed to remove all the air and boiled at 95 °C in a water bath for an hour followed by cooling. After opening the vacuum bags, drip water was removed and the meat patties were dried by gently tapping them with filtering paper. The weight of the patties was recorded and the drip volume was calculated as weight loss after cooking. Results were expressed as percentage decrease in drip volume against the control.

The water retention capacity of the ingredients was determined using method of AACC (0011).

Emulsifying capacity

In order to measure the emulsifying capacity of the ingredients, a modified method described by Swift et al.

(1961) was used. This method establishes the amount of fat stabilized by a given protein under standardized conditions. Into a 600 mL low form Griffin beaker, 25 g of each ingredient was weighted and dispersions were formed using the amount of water measured during the water retention test. Emulsions were formed at 15 °C by adding sunflower oil in increments to each suspension and stirring for 2 min using an 800 W Gorenje mixer. Viscosity and torque values were recorded at a given shear rate in relation to the temperature and time elapsed since emulsion formation by using a Brookfield DV-E digital viscometer. Sudden drop in torque and viscosity values were used as an indicator of emulsion breakdown and an indicator of the amount of fat the ingredient can emulsify.

Emulsion stability

The emulsion stability was evaluated similar to the methodology described by Yogesh et al. (2015). Different concentrations of yeast powders and mixtures of ingredients were used to stabilize several emulsion formulations (Table 1). The emulsions were then introduced into centrifuge tubes (2.8 cm diameter). Later on, after weighing and centrifugation (15 min at $2.500 \times g$ and 3 °C), the tubes were hermetically closed and boiled at 70 °C for 30 min. The tubes were reopened and placed for 1 h upside down onto collecting plates for total fluid release. Water content of the exudate was determined by heating the total fluid released for 16 h in an oven set at 105 °C. Fat released was considered the difference between the total fluid release and water release. The results have been expressed as g per 100 g of initial sample weight.

Texture profile analysis

The impact of yeast β -glucan addition to a finely comminuted meat system and subsequently over the texture of the final product has been evaluated by texture profile

analysis (TPA). Meat batter was formulated with the ingredients mentioned in Table 2, homogenization was performed using a SM45 STL bowl cutter (K+G Wetter; Biedenkopf, Germany) according to the finely comminuted meat products procedure, to a maximum temperature of $10 \text{ °C} \pm 1 \text{ °C}$.

A 3:1 mixture of yeast derived ingredients (GOLDCELL® IY B; GOLDCELL® BETA GLUCAN) was formulated, the mixture was added to meat batter aliquots in six percentages (1–6% w/w, each equivalent to a certain β -glucan concentration (Table 2). The meat samples were introduced into polyamide membrane using a vacuum filling machine (VEMAG ROBOT 500), and cooked into a boiling and smoking unit (Schwan RAKO-BAK-1500-E90/P3000) at 70 °C.

The samples were cooled overnight and texture profile analysis (TPA) was performed at room temperature using Instron (5944L1809; Bluehill 3 software) similar to the methodology described by Bourne (1978). Thirteen cubes of $1 \text{ cm}^3 \pm 1 \text{ mm}$ each were randomly taken from each sample and subjected to a two cycle compression test. The samples were compressed to 25% of their original height with a compression rate of 4 mm/s. Force–time deformation curves were obtained with a 50 N loading cell. The following parameters were quantified: *fracturability* (N), the maximum force required to break the sample, *hardness* (N), the maximum force required to compress the sample, *adhesiveness* (N $\times$ s), the area under the abscissa after the first compression, *cohesiveness* (dimensionless), extent to which the sample could be deformed prior to rupture, and *springiness* (m), ability of the sample to recover its original form after removal of deforming force.

Sensory analysis

The samples formulated for texture profile analysis (Table 2) have also been submitted to sensory analysis. All the samples have been manufactured in reformulation condition that aimed to decrease the curing salt and

Table 1 Meat emulsion formulations

Ingredients (% to raw meat batter)	Formulations																			
	Ca	Cb	P _{1.1}	P _{1.2}	P _{1.3}	P _{1.4}	P _{1.5}	P _{1.6}	P _{2.1}	P _{2.2}	P _{2.3}	P _{2.4}	P _{2.5}	P _{2.6}	P _{3.1}	P _{3.2}	P _{3.3}	P _{3.4}	P _{3.5}	P _{3.6}
Pork leg	70																			
Pork fat	15																			
Water	15																			
GOLDCELL IY B	0	0	0.5	0.5	1	1	1.5	1.5	0	0	0	0	0	0	0.25	0.25	0.5	0.5	0.75	0.75
GOLDCELL BG	0	0	0	0	0	0	0	0	0.5	0.5	1	1	1.5	1.5	0.25	0.25	0.5	0.5	0.75	0.75
Salt mixture	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b

a—Salt: 1.5%; Polyphosphate: 0.3%

b—Salt: 1%; Polyphosphate: 0.2%

Table 2 Meat batters formulated for TPA analysis

Ingredients (% to meat batters)	Formulations						
	C	P1	P2	P3	P4	P5	P6
Pork leg	60.22						
Pork back fat	13.89						
Iced water	23.16						
Curing salt	1.45						
Polyphosphates	0.23						
Soy protein	0.97						
Yeast ingredient mix*	0	1	2	3	4	5	6
β-glucan content	–	0.274	0.549	0.823	1.098	1.372	1.647

* Mixture of the two yeast derived ingredients used in the experiments (GOLDCELL® IY B and GOLDCELL® BETA GLUCAN), both containing β-glucan

C control, P1 ÷ P6 samples with different β-glucan content

polyphosphates (1.45% curing salt and 0.23% polyphosphates), while yeast ingredients were added to improve the sensory attributes. The sensory analysis has been performed by 12 trained panellists, and they have been asked to evaluate, on a scale of 1–5, five sensory characteristics. The sensory characteristics measured were: the intensity of perceived saltiness, the intensity of the yeast aftertaste, the intensity of colour, the intensity of smell and the appearance (visual texture) of the samples. The panellists have given ranks to the above mentioned sensory attributes, where 1 was very weak intensity or low perceived taste and 5 was given for very strong intensity or pronounced taste.

Statistical analysis

All parameters were measured in triplicate if not otherwise specified. The one way Anova test was employed to measure the statistical differences for a level of significance of $p < 0.05$ for each measurement, while the significant differences between the texture parameters were analysed by the Friedman test (pair wise; $p < 0.05$). All statistical analysis was performed using SPSS v.22 (IBM Corp., Armonk, NY, USA), and the graphics were created using Origin v.8 (OriginLab Corp., Massachusetts, USA).

Results and discussions

Behaviour of two yeast derived ingredients, one representing a yeast autolysate with high protein content (GOLDCELL® IY B) and the other consisting of a yeast dietary fibre concentrate (GOLDCELL® BETA GLUCAN), was studied in regard to water holding capacity, emulsion stability and emulsion capacity. The test results were used to determine the overall amphiphilic action of the two ingredients, by evaluating their interaction with

water and oil, in order to establish a suitable proportion of the two in the elaboration of a technological functional mixture.

Water holding capacity

The results for the water holding capacity studied in model system are illustrated in Fig. 1. Due to the fact that at low concentrations of the two ingredients (0.5%) the water holding capacity test results have a similar distribution, the experiment has been performed at higher yeast ingredient concentrations (1 and 1.5%). Reproducible tests were conducted at higher yeast concentrations to improve the accuracy of the results. Tests have concluded that GOLDCELL® BETA GLUCAN can hold almost twice the amount of water when compared to GOLDCELL® IY B. Centrifugation test confirmed the findings of the meat model system experiment, GOLDCELL® BETA GLUCAN (1: 8.08 ± 0.06 w/w) retaining a double amount of water when compared to GOLDCELL® IY B (1: 4.16 ± 0.12 w/w). This behaviour is supported by the distinct nature of the two ingredients: long chain dietary fibres, which are found in GOLDCELL® BETA GLUCAN, are known to retain large amounts of water, while high concentration of proteic ingredients, like those found in GOLDCELL® IY B, are capable to have a better hydrophobic activity than fibres. The use of a mixture between GOLDCELL® BETA GLUCAN and GOLDCELL® IY B added to meat batter formulation, from a water retention point of view, could generate lower levels of low nutritional value hydrocolloids used for the stabilization of meat formulations. A mixture of yeast proteins and fibres could be used for added value to the final product when frozen meat is used in the manufacture of finely comminuted meat products, where high value meat proteins are commonly lost through the exudation phenomenon. Optimal levels of yeast protein and fibres, added

Fig. 1 Water retained at given concentrations of yeast ingredients added to model meat emulsions, recorded as percentage decrease in drip volume compared to control

to meat products in such a way that it would not affect the textural characteristics of the final products could translate into less free water available for the microorganisms activity and therefore in longer shelf life high nutritional products.

Emulsifying capacity

The emulsifying capacity of the studied yeast ingredients has a significant impact over the stability and the production yield of the meat product. Besides the fact that GOLDCELL[®] BETA GLUCAN has been proven to absorb twice the amount of water when compared to GOLDCELL[®] IY B, the two ingredients have a different behaviour regarding fat stabilization as well. The yeast ingredient GOLDCELL[®] BETA GLUCAN, is able to stabilize up to two parts fat, destabilization behaviour being recorded after the second oil addition, during and after the fat incorporation (Fig. 2). Yeast ingredient GOLDCELL[®] IY B, has been able to successfully stabilize up to five parts oil, which is a significantly different ($p < 0.05$) behaviour when compared to the yeast fibres concentrate (GOLDCELL[®] BETA GLUCAN). After each oil addition viscosity values of the emulsion have increased proportionately with the decrease of emulsion stability, illustrated by the ever decreasing slope for each increment (Fig. 2). This behaviour is attributed to the difference in composition of the two yeast powders, especially due to the protein content, which is significantly higher in GOLDCELL[®] IY B (33.201 ± 0.78) when compared to GOLDCELL[®] BETA GLUCAN (2.082 ± 0.02). The emulsion capacity test has been performed in order to measure the quantity of fat that each yeast ingredient can interact with and form a stable system, in a standalone

manner at neutral pH. The results of this test can provide useful information into the formation of ready to use shortenings that can be later used in other food systems (e.g. mayonnaise). Because the “meat emulsion” system is a collection of multi phase systems, operating at different pH and ionic strength values, the two ingredients were further submitted to a emulsion stability test.

Emulsion stability

The behaviour of water in meat product formulations is of great importance and is linked to a series of factors (*post mortem* state, pH, salt, polyphosphates, added proteins and hydrocolloids, etc.). Bound or free, water greatly impacts the product yield, the microbiological, sensory and the quality characteristics of the final product. Exudate and water released after cooking is very important in meat emulsion formulation as it can provide valuable insight into the system stability. The level of added salt and polyphosphates changes the ionic strength of the medium with direct implication on meat protein extraction, solubilization and system stability. Studies have reported a limit for salt reduction in finely comminuted meat sausages (below 1.74% and above 1.23% salt) where the functionality of the meat proteins extracted is affected, thus decreasing the yield (Aaslyng et al. 2014). This study aims to evaluate the impact of yeast ingredients addition to finely comminuted meat formulations where salt levels are below the above mentioned threshold.

Several meat emulsion systems were formulated for stability evaluation (Table 1). Total fluid release (TFR), water release (WR) and fat release (FR) have been measured for samples formulated at different ionic strength with different contents of yeast powders. Three concentrations (0.5, 1 and 1.5%) of both yeast ingredients as well

Fig. 2 Viscosity behaviour of GOLDCELL[®] IY B and GOLDCELL[®] BETA GLUCAN

as a 1:1 mixture were added to meat formulations. For each yeast ingredient concentration studied, the ionic strength has been also varied by using two different concentrations of salt and polyphosphate (a = 1.5% salt + 0.3% polyphosphates; b = 1% salt + 0.2% polyphosphates).

The control sample formulated with “a” registered 5.13% ($p < 0.01$) lower values of the TFR when compared to the control formulated with “b”.

No significant impact on TFR was recorded when adding yeast derived ingredients to meat emulsion systems formulated with “a” for the concentration values of 0.5% and 1% ($p < 0.05$). There is however significant impact ($p < 0.05$), for the concentration value of 1.5% (Fig. 3). The combination of GBG 1.5%—“a” records a 3% TFR decrease and GIYB 1.5%—“a” a 4.4% TFR decrease, when compared to control. Thus, GIYB 1.5% manages to reduce the TFR slightly under 15% due to its high protein content (33.201 ± 0.78), property that can prove to be of great potential for improving the product yield.

When using the combination of salts “b”, the ionic strength of the medium decreases, and GIYB records no significant modifications of TFR, when compared to control, for the low concentration intervals (0.5 and 1%). However, we do record a 2% TFR decrease when using GIYB at 1.5% levels. The behaviour of GBG is the most intriguing, as the combination GBG—“b” records significant reduction of TFR even at low concentrations (approximately 2% TFR reduction when adding 0.5% or 1%) and a 4% TFR reduction at 1.5% level (Fig. 3).

Both yeast ingredients manifest their stabilization action by interacting with water, WR being the major parameter reduced. However, at a concentration of 1.5% added yeast ingredients, there is a higher amount of FR compared to controls. Dietary fibres are known to bind water immediately and to be easily incorporated by meat batters, thus controlling their viscosity and guaranteeing optimum consistency (Sindelar and Houser 2009). These findings are in agreement with other studies where the cooking yield and emulsion stability of frankfurters were increased when the formulation contained dietary fibres (Kim et al. 2014).

Texture profile analysis

While the textural parameters for P1 (0.274 mg β -glucan added) were not significantly different compared to control ($p < 0.05$), we do observe a certain dynamics for the other samples.

Two texture profiles were plotted (Fig. 4 a), samples formulated with β -glucan in a certain concentration range (P1—0.274 mg to P3—0.823 mg) have had similar textural profiles to control while the samples containing more β -glucan (P4—1.098 mg—1.647 mg β -glucan) registered modified textural profiles.

Fig. 3 The impact of yeast derived ingredient addition to meat emulsions formulated with two salt mixtures. Results are expressed as % TFR from initial samples size, where samples with “a” contain 1.5% salt and 0.3% polyphosphate, and samples with “b” contain 1% salt and 0.2% polyphosphate, in accordance with Table 1

Cohesiveness and springiness does not vary significantly for all the tested samples ($p < 0.05$) therefore the internal structure of the product is not affected. Adhesiveness values decrease significantly with the addition of yeast derived ingredients, thus adding β -glucan to finely comminuted meat formulations may decrease the perceived stickiness sensation associated with this type of products.

Adding yeast derived ingredients to meat batters significantly increased the water of the final product ($p < 0.05$), from 57.7% in control to 64% in P6 (1.647 mg β -glucan, highest quantity added). This, in turn, influenced the fracturability and hardness parameters by registering lower values with the increase in β -glucan content. Therefore, the finely comminuted meat matrix, to the formulation of which a mixture of yeast dietary fibres and proteins were added, retains the structural cohesiveness and has improved stability due to added emulsifying capacity of the two yeast ingredients. The lower values registered for hardness, show a decrease in the necessary force required for the slicing of the product. The findings of this test show that yeast fibres and proteins, added to a certain level (P3—0.823 mg) can be used in reformulated meat batters, without the offset of detrimental textural parameters in the final product.

Sensory analysis

The addition of nonmeat proteins and fibres could have negative impact on final product sensory acceptability. Justified by the meat like taste and aroma noticed in the yeast ingredient autolysate, the two yeast ingredients have

Fig. 4 **a** TPA of the meat samples formulated with yeast β -glucan. **b** Sensory analysis of the meat samples formulated with yeast β -glucan. For both **a** and **b**, average values are plotted with no significant differences for samples P4, P5, P6 (dotted line) and for

samples M, P1, P2 and P3 (solid line), where M is the sample without added β -glucan and Ps are the samples containing different quantities of added β -glucan (mg/100 g meat batter) according to Table 1

been added to reformulated meat batters. Two significantly different profiles have been obtained ($p < 0.05$), where P1, P2 and P3 have had similar sensory results to control, and samples P4, P5 and P6 have registered different results when compared to control (Fig. 4 b). The results obtained for samples up to P3 (0.823 mg β -glucan), illustrated by the solid line profile, have registered better appearance, colour and smell intensity when compared to the higher concentration β -glucan containing samples. The latter however, registered better results regarding the salt intensity parameter, indicator that the yeast derivatives can indeed be used to improve the perceived saltiness in meat, even in reformulation conditions in regard to salt. Because the boundary between P3 and P4 is where the sensory attributes shift towards lesser acceptability, the results of the test suggest going as high as 0.823 mg β -glucan (P3) when reformulating meat batters, without negative impact on the sensory attributes. Even if these results are dependable on the type of yeast derived ingredients used, similar studies that dealt with the reformulation of frankfurter type products and have added dietary fibres from various sources, to a certain extent, have registered acceptable sensory scores for the final product (Choi et al. 2014; Kim et al. 2016).

Conclusion

Apart from increasing the nutritional value, yeast β -glucan has proved to be a new and natural alternative that can successfully be used to reformulate meat batter products. The use of yeast derived ingredients when reformulating meat batter products can be a great solution to minimize cooking loss. Adding yeast β -glucan to meat batters help

maintain the structural cohesiveness of the final product, while slightly decreasing the hardness, perspective that could be employed for either developing products destined for children and elders or clean label products for all consumers. The yeast derived ingredients can be used to increase the perceived saltiness of the meat reformulated products while retaining acceptable sensory attributes.

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