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SOME ASPECTS OF BAKING INDUSTRY WASTES UTILIZATION IN BIOETHANOL PRODUCTION

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Summary. Present work describes possibilities of recycling wastes from baking industry in production of bioethanol. It was presented that along with development of baking industry amounts of bread waste, of low value for reprocessing in food industry, is increasing. These wastes could be processed for production of ethanol fuel as a cheap alternative to traditional crop raw materials. Reasons of waste formation in bakeries, changes in flour ingredients during baking and its influence on mash composition are describe along with latest achievements in production of ethanol from residual bread.

Key words: waste bread, bioethanol, recycling

INTRODUCTION

Social and economical changes and continuous development of industry causes that consumption of fossil fuels is very high, which can lead to its depletion. Such intensive exploitation is also a major factor in environmental pollution. Biofuels, as alternative sources of energy may be the proper solution to these problems. Among commercially available biofuels for special attention deserves dehydrated ethyl alcohol derived from plant products in the course of ethanol fermentation, the so-called bioethanol. The use of ethanol as an alternative energy source or fuel component creates the need for searching the solutions to reduce costs of its production. Particular attention is paid to the possibility of using cheap raw materials, new technological solutions and effective fermenting microorganisms [Aldiguier et al. 2004, Karimi et al. 2006, Krishnan et al. 2000, Kupczyk & Ekielski 2002, Linde et al. 2007, Prasad et al. 2007, Zbieć 2002].

First-generation biofuels are produced from raw materials used in food industry, and therefore top priority in the development of liquid biofuels market is the development

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of their production from waste materials or not used for food production (second generation biofuels) [Kim & Dale 2004, Ohgren et al. 2006, 2007]. Development of technology for the production of bioethanol based on agro-food industry waste materials, will reduce the cost of ethanol production and help eliminate these wastes from the direct trade. Measurable economic and environmental aspects of such proceedings are also significant. Results of previous studies [Kawa-Rygielska & Dziuba 2006, Kawa-Rygielska 2007, Ohgren et al. 2006] indicate that the production of bioethanol can be used in a wide range of waste products of food industry. These include banana peels [Oberoi et al. 2011], waste potato peels [Arapoglou et al. 2010], municipal solid waste [Jensen et al. 2010], domestic food waste [Kim, Lee & Pak 2011], cassava grate waste [Agu et al. 1997], and many others.

Especially noteworthy are baking industry wastes such as bread after the expiration date, or waste dough from production lines. These raw materials contain from 50 to 70% of total carbohydrates, including significant quantities of starch [Dewettinck et al. 2008]. Therefore they may be in the area of interest to distillers, especially as the amount of waste in the bakery in recent years has increased [Andrzejewska 2009].

The purpose of this paper is to review the latest achievements in the utilization of bakery wastes to bioethanol. Furthermore the reasons for formation of wastes during the bread production and distribution, current methods for its utilization and the physicochemical alterations of bread ingredients during baking, which may affect its suitability as raw material for ethanol production, were described on the basis of published investigations.

WASTE FORMATION DURING BREAD PRODUCTION AND SUPPLY

The bakery wastes can be formed during the manufacturing process, storage and supply of bread. Differentiation of baking value and the lack of quality control of flour, the mistakes committed in the process of dough preparation, fermentation and baking, as well as poor storage and transport conditions are the cause of the defects of bread, which would eliminate them from trading [Ceglińska 2002, Tsarouhas 2009]. The reason for increasing amount of waste in the baking industry are the high customers requirements as to the quality of bread and variety of its product range and willingness to buy bread "straight from the oven". Bakeries which want to meet these requirements are implementing new technologies such as deferred baking (baking from frozen dough), baking pre-roasted dough bites or baking bites subjected to controlled fermentation. These technologies are designed to provide consumers with hot bread in almost every time [Vulicevic et al. 2004, Kot 2005, Sobczyk 2006, Gellynck et al. 2009]. Recipes are also being developed for new kinds of breads with improved nutritional value and to enhance trade offer. Apart from increased supply of bread it can also be observed reduction in demand. According to Ceglińska [2002] the reason for this fact is high availability of different types of bread on the market. Reducing the demand for bread may also result from wrong conviction of large group of consumers that bread, as a product containing large amounts of carbohydrates, and as a high-energy food, should be restricted in their daily diet.

In Poland over 1.7 million tons of bread are produced every year [CSO 2010]. This suggests that waste production by bakeries can reach even 170 thousand tons annually. There are no data about amounts of bakery wastes recycled however due to food safety it is limited.

WASTE BREAD RECYCLING IN BAKERIES

On one hand, supply growth and, secondly, reduction in demand for bread causes that it is produced in excess and bakeries have been receiving returns from shops. The analysis carried out in a few medium-sized bakeries showed that returns of bread, including unsold bread, remain in the bakery ranges about 5–8% of total production, and often exceed even 10% [Dziugan 2009]. This raises the problem of utilization of large amount of waste. Current methods for waste bread utilization include: burning returned pastries, disposal by composting or transfer to farmers for animal feed if they are not contaminated by molds. Returns sent to the bakery can also be used to replace the part of rye flour to the baker's output rye sour [Dziugan 2009, Kownacki 2006]. It is possible to use bread returns in the ongoing production of bread, however, it is connected with specified requirements. For reprocessing can not be used bread with sprinkles, bread crumbs, cereal grains and foreign fillings, it also can not be infected by fungi or affected by potato disease, chalk, dirt or water. It must be safe for consumers. Therefore, the manufacturer should be able to confirm that the process technology used in bread manufacturing from the repayment meet health protective requirements [Staszewska 2008]. Storing of bread destined for recycling should not take more than 48 hours. It should be stored in clean containers, on shelves (to avoid mold contamination of raw material), in dry, ventilated and regularly cleaned rooms. Wheat bread is mostly destined to bread crumbs and wheat-rye bread for the preparation of rye sour in sour tanks, when making an acid fermentation by lactic acid bacteria starter cultures [Gül et al. 2005, Plessas et al. 2011]. Using bread contaminated with bacteria *Bacillus subtilis*, causing "potato disease", for rye sour manufacturing may require decontamination of tanks and utilization of contaminated bread, acids and dough which involves significant costs [Rosenkvist & Hnasen 1995, Staszewska 2008]. Some authors suggests to use wasted bread in hydrogen production [Doi et al. 2009].

CHANGES IN BREAD DURING BAKING AND STALING

Assessing the possibility of using bakery waste for bioethanol production attention should be paid to different aspects which can significantly affect the course and final effects of ethanol fermentation process. Raw material characteristics and selection of conditions of its preparation plays a crucial role.

For the traditional distillery raw materials, characterized by good quality, most efficient course of determining the parameters of technological operations are specified. Application of new, unconventional materials requires detailed assessment, including determination of carbohydrates, especially starch, which, after further preparation in the mashing process, are a source of sugars for yeast cells undergoing the process of fermentation and decide about efficiency of the process [Stecka et al. 1996, 1998].

Preparation of waste bread mash is related to some difficulties. This is due to the fact that during the formation of dough and baking it interaction takes place between the components such as proteins, carbohydrates and lipids [Miś 2005, Keetels et al. 1996]. Szajewska and Териńska [2004], emphasizes that during baking starch grains are surrounded by monoglycerides what induces formation of insoluble complexes that hinder the merger of amylose in the crystalline structure. Research conducted by Ottenhof and Farhat [2004] however showed, that kinetics and extent of amylopectin retrogradation is significantly affected by gluten.

Soon after baking begins the process of aging or bread staling. During bread aging its crumb decreases the ability to bind with water, starch solubility and susceptibility to the enzymes, and the degree of starch crystallization is increasing [Gambuś 1997]. Other ingredients of bread, such as gluten proteins and pentosans, may affect staling, but the size and nature of their participation in this process have not been known in a detailed way [Szajewska & Ceglińska 2004]. The reasons for difficulties in the preparation of bread mashes may also involve the fact that some in the bread starch remain intact, as during dough production certain amount of water is added which is insufficient for complete starch gelatinization during bread baking. Gelatinised and mechanically damaged starch is more susceptible to amylolytic enzymes. Moreover, dextrins and sugars (dissolved in water) formed during baking, in the bread crust undergo condensation and polymerization under high temperature, part of sugars which are subjected to caramelization, may negatively affect the process of mashing [Ebrahimi et al. 2008].

Fermentation of mashes is effective when the temperature restrictions during mashing of raw material, fixed dose of enzyme preparations, including non-amylolytic, are maintained [Kapela & Solarek 2004, Solarek 2001]. Optimizing the parameters of the fermentation process requires the knowledge of kinetics of starch transitions during mashing. Analysis of carbohydrates found in complex fermentation environment, which is the process of hydrolysis of starch is possible by using high performance liquid chromatography. The first phase of the mashing process is particularly important, because in it there take place significant changes in the composition of carbohydrates, which determines subsequent fermentation process efficiency and length.

ACHIEVEMENTS IN PRODUCTION OF ETHANOL FROM WASTE BREAD

According to own studies, preparation of mash from waste is connected with certain difficulties resulting from the formation of complexes that result from interactions of particular components of the dough. In addition, the process of starch retrogradation and colored compounds originating from the Maillard reaction, affects the limited efficiency of the fermentation process of expired bread [Michalska et al. 2008].

In preliminary tests, conducted at the Division of Fermentation Technology at Wroclaw University of Environmental and Life Sciences, conditions of waste wheat-rye bread mashing were optimized. The best results were achieved using an initial phase preceding the phase of starch liquefaction and gelatinization, using an additional enzyme preparation. This preparation contained rich complex of enzymes: α-amylase, β-glucanase, pentosanase, cellulase, and protease. Modification of mashing process led to increase in efficiency of fermentation from 350 to 366 g of ethanol from 1000 g of initial bread dry matter [Kawa-Rygielska et al. 2012]. Similar results were obtained by Ebrahimi et allii [2008] by fermentation of mashes prepared from wheat bread. Also different types of bakery wastes (waste dough from processing line, expired pastry and mix of these materials) were tested [Kawa-Rygielska & Pietrzak 2011a]. In that case the best ethanol yield was obtained from waste dough due to limited interactions between flour ingredients. Furthermore suitability of bread contaminated by fungi was studied. Obtained results showed that it also could be processed however fermentation efficiency was lower in comparison to not contaminated bread (ca. 250 g of ethanol per 1000 g of raw material dry matter) [Kawa-Rygielska & Pietrzak 2011b].

CONCLUSIONS

Waste bread could be used as a raw material for ethanol production yielding, depending on the processing technology ca. 350–366 g ethanol per kilogram of resource. Its high availability, low price and advantageous chemical composition speaks for its use. However due to interactions of flour ingredients additional technological treatment (enzymatic hydrolysis of non-starch polysaccharides and proteins) should be applied for efficiency improvement. Moreover bread contaminated by mold could be used in ethanol producing plant however by the cost of lowered yield (ca. 250 $g \cdot kg^{-1}$).

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WYBRANE ASPEKTY WYKORZYSTANIA ODPADÓW PRZEMYSŁU PIEKARNICZEGO DO PRODUKCJI BIOETANOLU

Streszczenie. W pracy przedstawiono możliwości wykorzystania odpadów z przemysłu piekarskiego do produkcji bioetanolu. Z dotychczasowych doniesień wynika, że wraz z rozwojem piekarstwa przemysłowego wzrosła ilość pieczywa o niskiej wartości stanowiącego produkt odpadowy, który nie może być wykorzystywany jako środek spożywczy. Odpady te mogą być tanią alternatywą dla tradycyjnych surowców zbożowych w procesie produkcji etanolu przeznaczonego na paliwo. W pracy opisano przyczyny powstawania odpadów w piekarniach, zmiany składników mąki podczas wypieku i ich wpływ na proces zacierania, a także najnowsze osiągnięcia w produkcji etanolu z pieczywa odpadowego.

Słowa kluczowe: pieczywo odpadowe, bioetanol, recykling