Croatian Journal of Food Science and Technology
journal homepage: www.ptfos.unios.hr/cjfst/

Review paper *DOI: 10.17508/CJFST.2018.10.1.04*

Production of third-generation snacks

JELENA PANAK BALENTIĆ[1], JURISLAV BABIĆ[1], ANTUN JOZINOVIĆ[1*], ĐURĐICA AČKAR[1], BORISLAV MILIČEVIĆ[1], BENJAMIN MUHAMEDBEGOVIĆ[2], DRAGO ŠUBARIĆ[1]

[1]*Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek, Franje Kuhača 20, 31000 Osijek, Croatia*
[2]*University of Tuzla, Univerzitetska 8, 75000 Tuzla, Bosna i Hercegovina*

ARTICLE INFO

Article history:
Received: October 16, 2017
Accepted: January 12, 2018

Keywords:
indirectly expanded,
3G snacks,
third generation snacks

ABSTRACT

Extruded snacks are products which are easy to consume, tasty, crispy, with thousands of shapes, flavours, textures and are consumed worldwide. They can be expanded directly or indirectly. Directly expanded products are cooked, expanded, shaped and cut off the extruder, dried and packaged. It is a less complicated process than the indirect expansion, products have low bulk density, and are seasoned with different types of flavours and oils. Indirectly expanded products are stable during storage and have high bulk density, provide opportunity to produce a wide range of products. Different types of raw materials (corn, potato, wheat, oat, by-products of food industry, etc.) and combination of ingredients can be incorporated into the products. Non-starch ingredients such as protein, fibre, vitamins and minerals are more likely to be incorporated into indirectly expanded products than into directly expanded products. This makes them delicious, healthier and more interesting to customers. The most commonly used ways of expansion are deep fat frying, hot-air puffing and microwave heating.

Introduction

During recent decades life has gotten busier, people are inclined to eat "ready to eat" food, food which is easy to consume, with minimal need for further processing. Extruded snacks are example of such products, and they are consumed worldwide. Extrusion provides opportunity to produce wide range of products such as snack-foods, baby-foods, breakfast cereals, noodle, pasta and cereal-based blends. It is also possible to enrich extruded snacks with nutritionally valuable ingredients such as protein, and fiber rich ingredients like legumes or whey protein addition, fruits and vegetables, or by-products of food industry, as reported by many studies (Jozinović et al., 2014; Jozinović et al., 2016; Kosović et al., 2016; Larrea et al., 2005; Obradović et al., 2014; Obradović et al., 2015a; Obradović et al., 2015b; Panak Balentić et al., 2017; Stojceska et al., 2008; Stojceska et al., 2010). Foods can be expanded directly by extrusion (2nd generation product), or indirectly by hot-air puffing, deep fat frying, baking or microwave heating (3rd generation product). Extrusion systems for production of 3rd generation snacks are economical to run, efficient, products are with long shelf life, tasty and acceptable for consumers (Huber, 2001; Moraru and Kokini, 2003; Tovar-Jímenez et al., 2016). This review will present literature data based on three ways of expansions as well as short introduction to the description of product, process and raw materials for production.

Description of product

Third-generation snacks (3G) or pellets are also called semi or half products, because after extrusion cooking they are dried to a stable moisture content and then expanded by frying in hot oil, puffing in hot air or microwaving and infrared heating as new variants. After expansion products are spiced with various types of spices and then packaged and sold as ready-to-eat (RTE) snacks. They can also be flavoured before

*Corresponding author E-mail:
ajozinovic@ptfos.hr

expansion and sold as pellets, for preparation at home (Sevatson and Huber, 2000).
Because of their stability during storage and high bulk density, 3G snacks provide opportunity to produce a wide range of products. Different types of raw materials and combinations of ingredients can be incorporated into the products (Huber and Rokey, 1990). Basic materials that are usually used are: flours (corn, potato, rice, wheat, oat, etc.), starch (corn, wheat, potato, tapioca), liquid shortenings and monoglyceride. It is possible to add flavour or nutrient containing ingredients such as meat (shrimp, crab, chicken, beef), vegetable powders or by-products of food industry (sugar beet pulp, apple pomace, tomato pomace, bran, etc.), milk components (yogurt, cheese, whey) or any other flavour that will be interesting to the customer (pizza, ham, onion, etc.).

Process description

There are two types of processing classifications: cold forming extrusion (40-70 °C, 60-90 bar) and cooking extrusion (130-180 °C, 120-250 bar). If cold forming extrusion is used, ingredients must be pregelatinized, because of optimal expansion of the final product. After the dry ingredients have been uniformly blended, it is possible to apply liquid ingredients such as shortenings, flavours etc. as sprays in batch mixer or by injection into the extruder. It is very important to combine temperature, residence time and moisture content during extrusion in such way that the starch components are completely gelatinized, i.e. the mixture is completely cooked (Schaaf, 1992; Huber, 2001).

Typical extrusion processing conditions are 100-150 °C, 20-25% moisture content and 30-45 seconds residence time. Specific mechanical energy input is usually low as the main portion of energy required for starch gelatinization is supplied from thermal energy. Cooked, densified and shaped products extruded through the forming die contain 20-25% moisture. It is necessary to lower the moisture to approximately 12% by proper drying, which is also a critical step in the production of 3G snacks. Before the consumption 3G snacks are most often expanded in hot oil or air (Huber, 2001).

Typical formulas for 3G snacks

Wide range of raw materials can be selected for production of 3G snacks. To maximize the expansion of the final product it has to contain relatively high levels of starch. Levels of less than 60% total starch in recipe result in less expanded final product, increased crunchiness and firmer texture. Some typical formulations are represented in Table 1. Starch has many contributions to the final product, such as final expansion, flavour, caloric value, resilience, binding, viscosity, hardness, firmness, crunchiness etc. Because of that it is important which cereal grains, starch, proteins and other minor ingredients will be selected. For example, potato amylopectin starch is a better raw material for preparing foams than high amylose potato starch. Suggested reason is that amylopectin has better water holding capacity, based on its ability to swell in water. High amylose potato starch is not completely gelatinized, when bubbles are introduced in the gel, there is no sufficient strength to trap the bubbles and create pores (Sjoqvist and Gatenholm, 2005).

Table 1. Typical formulas for 3G snacks

Hard, Crunchy Texture	
92% Ground corn 5% Corn starch 0.5% Monoglyceride 2.5% Liquid shortening	Huber (2001)
94.5% Corn or wheat flour 5% Corn or wheat starch 0.5% Monoglyceride	Moscicki (2011)
Soft, Frothy Texture	
55% Corn starch 30% Wheat starch 14% Tapioca starch 1% Deoiled lecithin	Huber (2001)
56% Corn flour 27.5% Wheat starch 14% Tapioca starch 2.5 Vegetable oil	Moscicki (2011)
7% Wheat flour 9% Rice flour 80% Tapioca flour 13% Vegetable oil 1% Salt	Moscicki (2011)

To reduce stickiness, control expansion and to import more uniform cellular structure into the final product, different types of shortenings, vegetable oils, salts and emulsifiers are used. Salt is very useful in assisting moisture migration after dying. Baking soda gives special flavour and textural attributes after expansion. Monoglycerides may reduce expansion if they are added in levels 0.5% or above. The addition of additives like glycerol and polyvinyl alcohol in wheat flour during extrusion showed negative effects on the foaming of the extruded materials when heated by microwave radiation, even though the dielectric loss factor is even higher than that of the starch-based materials without additives (Peng et al., 2013). Different types of proteins and protein enrichments can be added in 3G snacks, such as meat (fresh shrimp, chicken, beef, etc.), dairy products (milk solids, cheese, yogurt), and legume proteins (soya, bean, pea). They can be added in amounts up to 30-35%, and still maintain high quality of the final product (Riaz, 2006). Bastos-Cardoso et al. (2007) showed that nonfood-grade whole potato flour has got good potential for use in the production of expanded pellets with acceptable functional properties. Blue corn and orange vesicle flour can also be used in production of 3G snacks, with high-quality physicochemical characteristics, with the potential health benefits derived from nutraceutical characteristics (Camacho-Hernandez et al., 2014; Navarro-Cortez et al., 2014; Tovar-Jiménez et al., 2015).

Expansion by deep-fat frying

Deep-fat frying is an unit operation that involves immersion, cooking and frying of food in hot oil, in which high oil temperature (e.g., 150 to 180 °C) facilitates rapid heat transfer and a short cooking time (30-40 seconds). Its goal is to combine short cooking times with inimitable characteristics such as color, taste, flavor, crust and texture. However, the temperature inside the fried-food product does not rise above 100 °C and that is why leaching of water-soluble components from the food is minimal. There are various means of reducing the oil content in fried-food products that have been studied, but most of fried foods still contain considerable amounts of oil. To describe oil absorption phenomena, three mechanisms are proposed: water replacement, cooling-phase effect and surface-active agents, but none of them could explain it completely (Dana and Sam Saguy, 2006; Huber and Rokey, 1990).

Water-replacement mechanism describes mainly oil uptake by relatively large voids in the fried food. Most of the oil is absorbed when the food is removed from the fryer. Oil's viscosity and product's microstructure and surface characteristics play key roles in affecting the amount of oil uptake. The formation of surface-active agents gives only a partial explanation for the increased oil uptake during prolonged frying. Higher oil uptake during extended frying is probably related to increased oil viscosity caused by polymerization reactions taking place in the degrading oil (Dana and Sam Saguy, 2006).

During expansion process, there are several critical factors for optimal expansion. Van der Sman and Broeze (2014a) investigated the validity of the hypothesis that expansion is optimal at the moisture content, where the glass transition and the boiling line intersect. They successfully confirmed this theory and developed a multiscale simulation model, which possesses very few fitting parameters. Later, they used that model to investigate the effect of salt on the expansion of starchy snacks during frying. They have found that the optimal expansion for salty snacks occurs under the same conditions as for snacks without salt. Salt is shown to influence both the boiling line and the critical is viscosity line, via a change of the glass transition. The optimal moisture content for salty snacks is lower than that of unsalted snacks (Van Der Sman and Broeze, 2014b).

Texture and flavor are the most important attributes of fried foods. Before frying, characteristics of the food, such as water content, size, types and amount of protein and starch, composition of coating materials and additives, are important factors, which influence the desired texture of the final product. Processing variables, such as frying time and temperature, cooling conditions, moisture control, etc., should also be considered (Shieh et al., 2004). Van Laarhoven and Staal (1991) studied rheology of the paste formed by gelatinization by extrusion during the production of 3G snacks. They also studied the influence of process conditions on sensory properties of the product. Conclusion is that soft texture and a smooth surface are attained at low temperatures and high moisture contents, but high temperatures and low moisture contents result in a hard and crispy texture. Bahramparvar et al. (2012) investigated influence of different temperatures and times on textural and sensory properties of snacks fried in oil. They have concluded that deep-fat frying conditions played a significant role on the texture and sensory attributes of pellet snacks. Crispiness is directly affected by changing temperature (150, 170 and 190 °C) and time (0.5, 1.5, 2.5, 3.5 and 4.5 min) of frying. Force-deformation curves obtained through the uniaxial compression revealed different magnitudes of forces as a function of frying parameters. Sensory attributes of crispness, hardness, color, greasy mouth coating and total acceptance changed significantly in various frying times or temperatures.

During production of a new type of product, it is desirable to survey consumers about the desired prototype in order to fulfill their expectations and requirements. Choi et al. (2007) in their research evaluated peanut-based, indirectly puffed extruded snack products using a consumer affective test, to determine the optimum formulation of ingredients and extrusion conditions for the production of snack prototypes and to verify the predictive models used for the optimization process. Snacks were produced by an extrusion process with partially defatted (12% fat) peanut flour (30%, 40%, 50%) at different levels of screw speed (200, 300, 400 rpm) and feed rate (4, 5, 6 kg/h). Extrudates were dried to obtain half-products (11% to 12% MC) followed by puffing with deep-fat frying at 200 ºC for 35-40 sec. The puffed snack prototypes were subjected to consumer acceptance test. Grades were higher than 6.0 (= like slightly) for all products produced within the experimental factor ranges, but scores for appearance, flavour, colour and overall liking were lower than 6.0 for the product containing 50% peanut flour regardless of screw speed and feed rate. The feed rate had the largest effect on consumer attributes followed by peanut flour and screw speed. It was predicted by regression models. The optimum region was identified as the area beginning at the 42.0% to 43.0% peanut flour and 4.0 kg/h feed rates, rising to a maximum at 45% peanut flour and 4.6 kg/h feed rates and decreasing to the 33.0% to 34.0% peanut flour and 6.0 kg/h feed rates. The verification confirmed the capability of predictive regression models to identify peanut-based snacks, which were scored higher than 6.0 by consumer evaluation. This research is a part of dissertation (Choi, 2002) where the main purpose of research was the development of the half-product and its final snack type foods. The author concluded that the amount of peanut flour was the most responsible for the quality of the half-products and their final puffed products, followed by feed rate and screw speed, respectively. Less expanded snack products with smaller cell size were samples with higher amount of peanut flour resulting in an increase in the number of cells. It is possible to produce indirectly expanded snack product made from different ratios of peanut flour to rice flour using a twin-screw extruder and puffed by deep-fat frying.

Cereals and starch are the most used raw materials for production of extruded snacks. Snacks can be enriched with plant and/or animal protein, but extrusion of starch-containing materials mixed with animal muscle proteins is problematic because of a large number of side-effects. Primarily because of thermal instability of those mixtures and basic thermodynamic difference between protein and starch molecules and high sensitivity of muscle proteins of slaughtered animals and fish to denaturation. The addition of muscle protein usually reduces extrudate expansion, but it can be done efficiently by pellet production and indirect expansion with frying (Wianecki, 2007). The Evaluation of fish and squid meat applicability for snack food manufacture by indirect extrusion cooking was investigated by Wianecki (2007). He concluded that most of the animal protein vectors tested can be applicable in manufacture of starch-protein extrudates. Vectors for the final product quality depended on fish species, methods of meat separation and preservation, and methods of initial processing used. For example, lean fish supplied meat of better extrusion parameters than fat fish, because fat was found to significantly reduce the extrudate quality, while washing of fish minces improved their applicability as components of formulations to be texturized by warm extrusion.

Expansion by hot air

While conventional frying absorbs oil, hot air expansion is an alternative, typically reducing oil content from 30% to 10%. Pellets are exposed to heat, which evaporates water. For that type of product the most important is gelatinization and it depends on time, temperature and moisture. After expansion, products can be coated with an oil based flavoring (Guraya and Toledo, 1994).

Temperature is important for expansion of product, because below glass transition temperature (Tg), the starch does not flow and the structure does not expand, but above Tg the polymer acts mostly ‘‘rubbery’’ and expansion is easier. Expansion temperature increases linearly with Tg. Increasing the moisture content of pellets reduced the extent of expansion and salt addition was not important for expansion of the starch matrix, but both the puffing extent and the rate were increased by additions of sodium chloride or potassium chloride. The importance of the cation in the starch matrix apparently is due to an interaction of the cation with the starch. Addition of dextrin can increase the expansion ratio due to decreasing the viscosity (Chen and Yeh, 2000; Boischot, et al., 2003; Norton et al., 2011).

Expansion by microwave heating

Cooking, heating and expanding food with microwaves is fast, convenient and inexpensive technique. Food is placed in an electromagnetic field at room temperature, heat is produced in food and then it spreads outward. While feeding microwaves through foodstuffs, the routing and friction of the water molecules contained in the foodstuff results in the heating of the foodstuff. In some cases, the packaging may also develop heat when subjected to microwaves (Vujković et al., 2007).

Microwaves are a form of high frequency electromagnetic radiation of certain wavelengths. Although we cannot see them, we can be aware of their actions. In the same way as light goes through glass, plastic and air, microwaves pass through paper, glass, porcelain and plastic. There are two main mechanisms by which microwaves produce heat in food:

1. Dipole rotation - In the presence of an electric field, the polar molecule (most often water) tries to align and the polarity of the field changes. In this field, molecule behaves like a dipole and, while oscillating around the axis, acquires potential energy while trying to reach positive or negative pole. Collected energy is released as a random kinetic energy or heat.

2. Ion polarization – is the result of the electric field ions (carrying electrical charges) which are moving in the water and accelerating. They crush and kinetic energy turns into heat. The more concentrated the solution is, the higher number of the crushes. There are a lot of crushes on the microwave frequency resulting in the release of energy. Ion polarization is less important than dipole rotation (Robertson, 1993).

The mechanism of microwave expansion is based on the transition of amorphous matrix to the rubbery and flow states, occurring during microwave heating. Moisture generates the superheated steam which accumulates at nuclei in the glassy matrix, creating a locally high pressure. Matrix undergoes a phase transition (glassy to rubbery) and starts to yield under the high superheated steam pressure and expansion takes place. When moisture is lost from the matrix and microwave heating is stopped, the matrix cools down and reverts to the glassy state and the final structure sets. Collapse occurs when matrix is too soft (at high moisture) (Boischot, et al., 2003; Moraru and Kokini, 2003; Tovar-Jímenez et al., 2016**;** Gutiérrez et al., 2017). The mechanism of microwave expansion is shown in the state diagram shown in Figure 1.

As for the expansion by hot air and oil, and for microwave expansion expanded shape and air cell structure differ according to the degree of gelatinization of the pellets. Optimal expansion by microwave heating is achieved when the starch is approximately half-gelatinized and the moisture content in the pellets is about 10%. Moisture content of pellets is crucial in expansion behaviour, for completely dehydrated samples could not expand at all. Moisture is driving force in the microwave expansion of the pellets. For uniform air cell distribution and optimum product shape, the pellets should undergo sudden release of the superheated vapor during the microwave-heating (Lee et al., 2000; Sjoqvist and Gatenholm, 2007; Maisont and Narkrugsa, 2010; Delgado-Nieblas et al., 2012). Microwave power is important because the higher it is, the higher is temperature inside the product which causes a higher vapor pressure and higher volume expansion (Kraus et al., 2013). Barrel temperature of extruder is important for subsequent expansion of the product, with higher temperature, expansion index is higher, which is connected with development of amylose-lipid complexes (Aguilar-Palazuelos et al., 2006; Delgado-Nieblas et al., 2012).

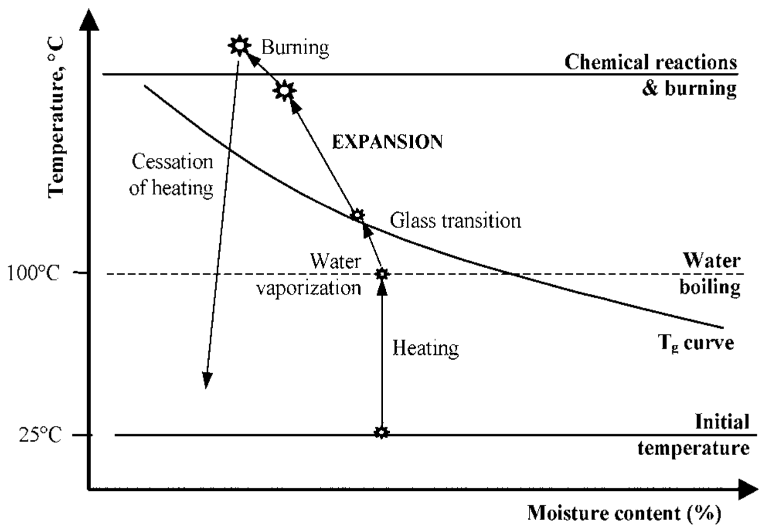

Fig. 1. State diagram for microwave expansion of cereal glasses (Boischot et al., 2003)

The addition of fat can also affect expansion of the pellets by microwave heating. Solid fat contributes greatly to expansion, but pellets that contain liquid fat have lower expansion volume and a coarser structure. The highest degree of expansion was obtained for extruded glassy amylopectin pellets containing 6% solid fat (Ernoult et al., 2002). The addition of sucrose caused a nearly linear increase in volume expansion of the product. Also, increasing sucrose content increased and number of pores. This was concluded by Kraus et al. (2014) on extruded, starch-based pellets during microwave vacuum processing. Maisont and Narkrugsa (2010) investigated influence of salt on puffing qualities of puffed rice during microwave heating. They soaked paddy rice in 2% salt solution and distilled water, than dried it and expanded by microwave oven. Paddy rice soaked in 2% salt solution produced a higher puffed yield than paddy rice soaked in water. The addition of salts reduces foam density and plasticizes cell walls (Zhou et al., 2006), unlike the addition of nucleation agent that refines cell structure, but increases foam density. Salt can also help in bonding between foamed pellets, during the production of foam blocks by the microwave-assisted moulding (MAM) method. Polytetrafluoroethylene (PTFE) was found to be an appropriate mould material for the MAM process (Zhou et al., 2007).

To improve volume, structure, and texture of expanded cereal products different types of gums such as carboxymethyl cellulose (CMC) and xanthan gum (XG) can be added into the product, because they have ability to affect moisture retention and rheological properties. Gimeno et al. (2004) investigated the effect of 1% addition of CMC and XG on the structural and mechanical properties of samples obtained by microwave expansion of glassy corn pellets. The addition of gums significantly improved the shape, structural and textural properties of the microwave-expanded samples. Their hypothesis is that the extended hydrocolloid macromolecules interpenetrated the polymeric starch matrix and created “holes” which served as additional nucleation sites for expansion.

The physical properties of foamed pellets are highly dependent on the raw materials and additives (Zhou et al., 2006). Van der Sman and Bows (2017) wrote a review about critical factors in microwave expansion of starchy snacks. They concluded that pellet formulation has a strong influence on the dielectric properties, due to complex interactions between the various ingredients found in the starchy snacks, such as biopolymers, water, sugars, oil and salt. Also, the physical state of the matrix is important, whether the matrix is in the glassy state or there are crystalline components which melt during heating.

Conclusion

Third-generation snacks are example of products where production technology has progressed considerably. Ways of expansion have been altered, the product composition, apart from the classic raw materials, is increasingly enriched with various substances originating from meat, fruit, vegetables etc. They can be packed in different ways, expanded before packing or filled for home expansion. With this simplicity and wide range of products, it strives to appeal the customer. However, since the trend of healthy diet has recently been dominant, there is possibility for further research and development of some new, healthier, nutritionally enriched 3G snacks. Alternative means of indirect expansion enhancement, such as supercritical fluid extrusion, natural aids etc., as well as packaging materials with desirable functional and environmentally friendly properties should also be researched.

Acknowledgments:

This work has been fully supported by Croatian Science Foundation under the project 1321.

References

Aguilar-Palazuelos, E., Zazueta-Morales, J. de. J., Martínez-Bustos, F. (2006): Preparation of high-quality protein-based extruded pellets expanded by microwave oven. *Cereal Chem.* 83(4), 363–369. https://doi.org/10.1094/CC-83-0363.

Bahramparvar, M., Moghaddam, T. M., Razavi, S. M. A. (2012): Effect of deep-fat frying on sensory and textural attributes of pellet snacks. *J. Food Sci. Technol.* 51(12), 3758–3766. https://doi.org/10.1007/s13197-012-0914-6

Bastos-Cardoso, I., Zazueta-Morales, J. de J., Martínez-Bustos, F., Kil-Chang, Y. (2007): Development and characterization of extruded pellets of whole potato (*Solanum tuberosum* L.) flour expanded by microwave heating. *Cereal Chem.* 84(2), 137–144. https://doi.org/10.1094/CCHEM-84-2-0137.

Boischot, C., Moraru, C. I., Kokini, J. L. (2003): Factors that influence the microwave expansion of glassy amylopectin extrudates. *Cereal Chem.* 80(1), 56–61. https://doi.org/10.1094/CCHEM.2003.80.1.56.
Figure: Available from: https://www.researchgate.net/publication/228752196_Factors_That_Influence_the_Microwave_Expansion_of_Glassy_Amylopectin_Extrudates Accessed October 11, 2017.

Camacho-Hernandez, I. L., Zazueta-Morales, J. J., Gallegos-Infante, J. A., Aguilar-Palazuelos, E., Rocha-Guzman,

N. E., Navarro-Cortez, R. O., Jacobo-Valenzuela, N., Gomez-Aldapa, C. A. (2014): Effect of extrusion conditions on physicochemical characteristics and anthocyanin content of blue corn third- generation snacks. *Cyta-J. Food*. 12(4), 320–330. http://dx.doi.org/10.1080/19476337.2013.861517.

Chen, C. M., Yeh, A. I. (2000): Expansion of Rice Pellets : Examination of Glass Transition and Expansion Temperature. *J. Cereal Sci.* 32, 32, 137–145. http://doi.org/10.1006/jcrs.2000.0332.

Choi, I.-D. (2002): Development, physical, and sensory characterization of extruded, indirectly puffed peanut-based snack products. Dissertation. Graduate Faculty, University of Georgia, Athens, Georgia, pp. 1-255. http://crsps.net/wp-content/downloads/Peanut/Inventoried%208.14/7-2002-12-1725.pdf Accessed July 19, 2017.

Choi, I.-D., Phillips, R. D., Resurreccion, A. V. A. (2007): Consumer-Based Optimization of a Third-Generation Product Made from Peanut and Rice Flour. *J. Food Sci.* 72(7), 443–449. http://doi.org/10.1111/j.1750-3841.2007.00457.x.

Dana, D., Sam Saguy, I. (2006): Review : Mechanism of oil uptake during deep- fat frying and the surfactant effect-theory and myth. *Adv. Colloid Interfac*. 128–130, 267–272. http://doi.org/10.1016/j.cis.2006.11.013.

Delgado-Nieblas, C., Aguilar-Palazuelos, E., Gallegos-Infante, A., Rocha-Guzmán, N., Zazueta-Morales, J., Caro-Corrales, J. (2012): Characterization and Optimization of Extrusion Cooking for the Manufacture of Third-Generation Snacks with Winter Squash (*Cucurbita moschata* D.) *Flour. Cereal Chem.* 89(1), 65–72.http://doi.org/http://dx.doi.org/10.1094/CCHEM-02-11-0016.

Ernoult, V., Moraru, C. I., Kokini, J. L. (2002): Influence of Fat on Expansion of Glassy Amylopectin Extrudates by Microwave Heating. *Cereal Chem.* 79(2), 265–273. https://doi.org/10.1094/CCHEM.2002.79.2.265

Gimeno, E., Moraru, C. I., Kokini, J. L. (2004): Effect of Xanthan Gum and CMC on the Structure and Texture of Corn Flour Pellets Expanded by Microwave Heating. *Cereal Chem*., 81(1), 100–107. http://doi.org/10.1094/CCHEM.2004.81.1.100.

Guraya, H. S., Toledo, R. T. (1994): Volume Expansion during Hot Air Puffing of a Fat-free Starch-Based Snack. *J. Food Sci.* 59(3), 641–643. https://doi.org/10.1111/j.1365-2621.1994.tb05582.x

Gutiérrez, J. D., Catalá-Civera, J. M., Bows, J., Peñaranda-Foix, F. L. (2017): Dynamic measurement of dielectric properties of food snack pellets during microwave expansion. *J. Food Eng.* 202, 1–8. http://doi.org/10.1016/j.jfoodeng.2017.01.021.

Huber, G. (2001): Snack foods from cooking extruders. In: Snack Foods Processing, Lusas, E. W., Rooney, L. W. (eds.), Boca Raton, USA: CRC Press, pp. 356–359.

Huber, G. R., Rokey, G. J. (1990): Extruded Snacks. In: Snack Food, Huber, G. R. (ed.), New York, USA: Van Nostrand Reinhold, pp. 123–129.

Jozinović, A., Šubarić, D., Ačkar, Đ., Babić, J., Miličević, B. (2016): Influence of spelt flour addition on properties of extruded products based on corn grits. *J. Food Eng.* 172, 31-37. http://doi.org/10.1016/j.jfoodeng.2015.04.012

Jozinović, A., Šubarić, D., Ačkar, Đ., Miličević, B., Babić, J., Jašić, M., Lendić Valek, K. (2014): Food industry by-products as raw materials in functional food production. *Hrana U Zdravlju I Bolesti: Znanstveno-Stručni Časopis Za Nutricionizam I Dijetetiku,* 3(1), 22–30. http://hrcak.srce.hr/126237 Accessed July 19, 2017.

Košović I., Jukić M., Jozinović A., Ačkar Đ., Koceva Komlenić D. (2016): Influence of chestnut flour addition on quality characteristics of pasta made on extruder and minipress. *Czech J. Food Sci.* 34: 166-172.http://doi.org/10.17221/451/2015-CJFS.

Kraus, S., Enke, N., Schuchmann, H. P., Gaukel, V. (2014): Influence of sucrose content on expansion of extruded, starch-based pellets during microwave vacuum processing. *J. Food Process Eng*. 37(6), 628–634. http://doi.org/10.1111/jfpe.12119

Kraus, S., Sólyom, K., Schuchmann, H. P., Gaukel, V. (2013): Drying Kinetics and Expansion of Non-predried Extruded Starch-Based Pellets during Microwave Vacuum Processing. *J. Food Process Eng*. 36(6), 763–773. http://doi.org/10.1111/jfpe.12045.

Larrea, M. A., Chang, Y. K., Martinez-Bustos, F. (2005): Some functional properties of extruded orange pulp and its effect on the quality of cookies. *Lwt-Food Sci. Technol.* 38(3), 213–220. https://doi.org/10.1016/j.lwt.2004.05.014.

Lee, E. Y., Lim, K. II, Lim, J.-K., Lim, S.-T. (2000): Effects of gelatinization and moisture content of extruded starch pellets on morphology and physical properties of microwave-expanded products. Cereal Chem. 77(6), 769–773. http://doi.org/10.1094/CCHEM.2000.77.6.769.

Maisont, S., Narkrugsa, W. (2010): Effects of Salt, Moisture Content and Microwave Power on Puffing Qualities of Puffed Rice. *Kasetsart J. (Nat. Sci.),* 44, 251–261. http://kasetsartjournal.ku.ac.th/kuj_files/2010/a1004071408001562.pdf Accessed July 19, 2017.

Moraru, C. I., Kokini, J. L. (2003): Nucleation and Expansion During Extrusion and Microwave Heating of Cereal Foods. *Compr. Rev. Food Sci. F.* 2(4), 147–165. http://doi.org/10.1111/j.1541-4337.2003.tb00020.x.

Moscicki, L. (2011): Snack Pellets. In: Extrusion-Cooking Techniques, Applications, Theory and Sustainability, Moscicki, L. (ed.), Weinheim, Germany: WILEY-VCH Verlag & Co. KGaA, pp. 81-89.

Navarro-Cortez, R. O., Aguilar-Palazuelos, E., Zazueta-Morales, J. J., Castro-Rosas, J., Hernández-Ávila, J., Gómez-Aldapa, C. A, Aguirre-Tostado, F. S. (2014): Microstructure of an Extruded Third-Generation Snack Made from a Whole Blue Corn and Corn Starch Mixture. *Int. J. Food Process. Technol.* 1, 10–17. http://doi.org/10.15379/2408-9826.2014.01.01.2.

Norton, A. D., Greenwood, R. W., Noble, I., Cox, P. W. (2011): Hot air expansion of potato starch pellets with different water contents and salt concentrations. *J. Food Eng.* 105, 119–127. http://doi.org/10.1016/j.jfoodeng.2011.02.014

Obradović, V., Babić, J., Šubarić, D., Ačkar, Đ., Jozinović, A. (2014): Improvement of nutritional and functional properties of extruded food products. *J. Food Nutr. Res.*, 53(3), 189–206. http://www.vup.sk/en/index.php?mainID=2&navID=34&version=2&volume=53&article=1927 Accessed July 19, 2017.

Obradović, V., Babić, J., Šubarić, D., Jozinović, A., Ačkar, Đ., Klarić, I. (2015a): Influence of dried Hokkaido pumpkin and ascorbic acid addition on chemical properties and colour of corn extrudates. *Food Chem.* 183, 136–143. http://doi.org/10.1016/j.foodchem.2015.03.045.

Obradović, V., Babić, J., Šubarić, D., Jozinović, A., Ačkar, Đ. (2015b): Physico-chemical Properties of Corn Extrudates Enriched with Tomato Powder and Ascorbic Acid. *Chem. Biochem. Eng. Q.,* 29(3), 335–342. http://doi.org/10.15255/CABEQ.2014.2159.

Panak Balentić, J., Ačkar, Đ., Jozinović, A., Babić, J., Miličević, B., Jokić, S., Pajin, B., Šubarić, D. (2017): Application of supercritical carbon dioxide extrusion in food processing technology. *Hem. Ind.* 71(2), 127–134. http://doi.org/https://doi.org/10.2298/HEMIND150629024P.

Peng, X., Song, J., Nesbitt, A., Day, R. (2013): Microwave foaming of starch-based materials (I) thermo-mechanical performance. *J. Cell. Plast.* 49(3), 245-258. http://doi.org/10.1177/0021955X13477439.

Riaz, M. N. (2006): Extruded Snacks. In: Handbook of Food Science Technology, and Engineering, Volume 4, Hui, Y. H. (ed.), Boca Raton, USA: CRC Press, pp. 168/6-168/7.

Robertson, G. L. (1993): Food Packaking- Principles and Practice. New York, USA: Marcel Dekker, pp. 383-391.

Schaaf, H.-J. (1992): Method of making expanded foodstuffs. Germany. US 5153017 A http://www.google.com/patents/US5153017 Accessed July 19, 2017.

Sevatson, E., & Huber, G. R. (2000): Extruders in Food Industry. In: Extruders in Food Applications, Riaz, M. N. (ed.), Boca Raton, USA: CRC Press, pp. 193–204.

Shieh, C. J., Chang, C.-Y., Chen, C.-S. (2004): Improving the texture of fried food. In: Texture in food, Kilcast, D. (ed.), New York, USA: CRC Press. Pp. 501-523.

Sjoqvist, M., Gatenholm, P. (2007): Effect of Water Content in Potato Amylopectin Starch on Microwave Foaming Process. *J. Polym. Environ*. 15, 43–50. http://doi.org/10.1007/s10924-006-0039-y.

Sjoqvist, M., Gatenholm, P. (2005): The Effect of Starch Composition on Structure of Foams Prepared by Microwave Treatment. *J. Polym. Environ.* 13(1), 29–37. http://doi.org/10.1007/s10924-004-1213-8.

Stojceska, V., Ainsworth, P., Plunkett, A., İbanoğlu, Ş: (2010): The advantage of using extrusion processing for increasing dietary fibre level in gluten-free products, *Food Chem.* 121(1), 156–164. http://doi.org/10.1016/j.foodchem.2009.12.024.

Stojceska, V., Ainsworth, P., Plunkett, A., İbanoğlu E., İbanoğlu, Ş. (2008): Cauliflower by-products as a new source of dietary fibre , antioxidants and proteins in cereal based ready-to-eat expanded snacks, *J. Food Eng.* 87(4), 554–563. http://doi.org/10.1016/j.jfoodeng.2008.01.009.

Tovar-Jímenez, X., Aguilar-Palazuelos, E., Gómez-Aldapa, C., Caro-Corrales, J. J. (2016): Microstructure of a Third Generation Snack Manufactured by Extrusion from Potato Starch and Orange Vesicle Flour. *J. Food Process Technol.* 7(3). http://doi.org/10.4172/2157-7110.1000563.

Tovar-Jiménez, X., Caro-Corrales, J., Gómez-Aldapa, C. A., Zazueta-Morales, J., Limón-Valenzuela, V., Castro-Rosas, J., Hernández-Ávila, J., Aguilar-Palazuelos, E. (2015): Third generation snacks manufactured from orange by-products: physicochemical and nutritional characterization. *J. Food Sci. Technol.* 52(10), 6607–6614. http://doi.org/10.1007/s13197-015-1726-2.

Van der Sman, R. G. M., Bows, J. R. (2017): Critical factors in microwave expansion of starchy snacks. *J. Food Eng.* 211, 69–84. http://doi.org/10.1016/j.jfoodeng.2017.05.001.

Van der Sman, R. G. M., Broeze, J. (2014a): Multiscale analysis of structure development in expanded starch snacks. *J. Phys. Condens. Matter* 26, 1–11. http://doi.org/10.1088/0953-8984/26/46/464103.

Van der Sman, R. G. M., Broeze, J. (2014b): Function Effects of salt on the expansion of starchy snacks : a multiscale analysis Multiscale model. *Food Funct.* 5, 3076–3082. http://doi.org/10.1039/c4fo00513a.

Van Laarhoven, G. J. M., Staal, G. (1991): Rheology of the Paste from Gelatinization by Extrusion During the Production of Third-Generation Snacks. *J. Food Eng.* 14, 53–70.

Vujković, I., Galić, K., Vereš, M. (2007): Ambalaža za pakiranje namirnica. Zagreb, Croatia: Tectus, pp.427-433.

Wianecki, M. (2007): Evaluation of Fish And Squid Meat. *Acta Sci. Pol., Technol. Aliment.* 6(4), 29–44. http://www.food.actapol.net/pub/3_4_2007.pdf Accessed July 19, 2017.

Zhou, J., Song, J., & Parker, R. (2006): Structure and properties of starch-based foams prepared by microwave heating from extruded pellets. *Carbohyd. Polym.* 63(4), 466–475. http://doi.org/10.1016/j.carbpol.2005.09.019.

Zhou, J., Song, J., & Parker, R. (2007). Microwave-assisted moulding using expandable extruded pellets from wheat flours and starch. *Carbohyd. Polym.* 69(3), 445–454. http://doi.org/10.1016/j.carbpol.2007.01.001.