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Vegan foods: Mimic meat products in the Italian market

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ABSTRACT

The current concern about meat consumption tackles many aspects: health, social life, food behaviours, animal welfare, natural resources exploitation. People are more sensitive about these topics and they are shifting individual food habits in favour of a more plant-based diet. Surveys provide a concise view of the increasing percentage of both vegetarians and vegans. The aim of the present research was to develop adequate recipes to prepare food products that mimic the shape and the texture of traditional würstel and Mortadella, focusing on the Italian market. The challenge faced was multiple: firstly, to maintain the similar characteristics of the traditional foods; secondly, to accomplish the consumer's requests; thirdly, to enlarge the market share of the food industries. The results obtained demonstrated that "mimic- würstel" and "mimic-mortadella" were created with vegan allowed ingredients and proteins of vegetal origin. In the case of "mimic-mortadella" the addition of tofu cubes tried to recreate the visual effect of fat globules.

Introduction

Origin and evolution of vegetarianism and veganism

The terms vegetarianism and vegan were derived from the ancient Latin adjective *vegetus* (healthy, vigorous). In particular, the International Vegetarian Union defines vegetarianism as a diet that excludes from the daily diet meat, fish and their derivates, based on ethical, religious, environmental believes, but it still accepts milk, dairy products and eggs. The first society ever created worldwide is the Vegetarian Society (founded in Sept 30th, 1847 in Ramsgate, UK) which coined the word vegetarian.

The origins of the concept of eating less meat and meat derivates are archaic when religious movements began, around the 6th century B.C. In the Eastern world, Hinduism and Buddhism proposed a food culture in favour of plant-based ingredients. In the Western world, the Greeks Pitagora and Platone where the first to embrace the principles of vegetarianism. Plutarco and Ovidio in the capital of the Roman Empire started to write about how the humans should eat from agricultural products without killing animals. During the centuries, the concept evolved in itself and in the motivations to take part to what was starting to be considered a 'movement'; on the contrary, it resisted the link with cultural and religious aspects. Philosophers of the stature of Voltaire and Jean-Jaques Rosseau in France during the Illuminism, or more recently Peter Singer and Tom Regan took position against the modern way of eating. Moreover, they were the witnesses of the drastic change of prospective: from a more social believe, vegetarianism became a personal choice in the food habits. Particularly in UK, this attitude assumed the form of a protest against the European colonialism, guilty of exploiting individuals, plants and animal resources to keep up with the general request of welfare. Nowadays, new interest and curiosity surround food culture and, more general, food habits. In Europe and U.S.A. scientists and consumers see clearer links between nutrition and health conditions (Timmer et al., 2016). Meat has been identified as one of the main issues in the debate of what we should eat: it tends to substitute many other plant-based ingredients, becoming the core part of the wealthy class's diet. As the Engel's curve demonstrates, when the income rises, its proportion spent on food decreases, even if the absolute expenditure on food increases (Chai and Moneta, Zimmerman, 2010, 2014;). This law suggests that consumers increase their expenditures for food products in percentage terms less than their increases in income. In economic terms, it means that the income elasticity of food demand is between 0 and 1. There are causal and direct mechanisms in the food consumption patterns of populations: when the middle and upper households dispose of higher incomes, they tend to increase the demand for livestock products, reducing the intake of grains and cereals (Timmer and Pearson, 1983).

At the beginning of 20th century, it started an intense debate about the consumption of dairy products. In 1944, two members of the society decided to establish the Vegan Society, using the word vegan as a term in contradiction with vegetarian, for the first time. It designated people who do not use products of animal origin for nutrition and

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clothing, favouring the ones of plant origin (de Haan et al., 2001). The official definition is: *"veganism is a way of living which seeks to exclude, as far as is possible and practicable, all forms of exploitation of, and cruelty to, animals for food, clothing or any other purpose"*. In fact, every individual is directly responsible for the usage of natural resources and as a consequence of the coexistence of all the inhabitants of the Earth (Alexandratos and Bruinsma, 2012; Boye et al., 2010).

Geographical diffusion and motivations

It is important to point out is that there is no unanimity of opinion on a precise definition of vegetarianism in different parts of the world, which makes the analysis more complicated. In Italy, the Institute for Political, Social and Economic Studies (EURISPES) recorded an increasing trend of vegetarians: from the 4.9% of 2012, then an increment of 0.6% in 2013; in 2014 it still raised at 6.5%, until 2016 with 7.1%. The trend decreased in 2015 and 2017, with percentages of 5.7% and 7.1%, respectively (Eurispes, 2017).

In the United States, in 2008, 3.2% of the adult Americans follow a vegetarian diet and among them 59% were women and 41% males (Vegetarian times, 2008). In 2011, 9% of the Germans were declared vegetarians (Agri-Food Trade Commissioner, 2011) as well as 4.5% of the British (Food Standards Agency, 2009). In Australia, 5% of the population has been identified as vegetarians with an increment in 2016 up to 11.2% (Roy Morgan Research, 2016). The percentage of Indians declared vegetarians was between 20% and 42% in 2003 showed that cultural and religious reasons are still predominant in the meat consumption.

Regarding a deeper analysis of the vegan sector in Italy, Eurispes (2017) reported that in 2016 the 1% of the Italian population declared to follow a diet based exclusively on plant-based foods. In 2017 the percentage triplicated, involving 1.8 million people. Specifically, the geographical diffusion is concentrated in big cities in the North-Western part of the nation, hired in manager and high remunerative positions; 58% of them are women with a university degree between the ages of 45–54. Even if the availability of statistics is fragmented and incomplete, it was possible to obtain data for U.S.A. in 2012, where 2% of the population declaring their involvement in the vegan diet. On the contrary, in 2014, only 0.5% of them, still have the same opinion. Nevertheless, the consumption of meat and meat-derivates was subjected to a drop of 12.5% from 2007 to 2012 (Asher et al., 2014).

The motivations that represent the pillars of the vegan choice are ascribable to the exploitation of natural resources to produce meat, with a consequently inefficiency in the feed conversion ratio (FCR). Just to mention the beef example, to obtain 1 kg of weight, it is necessary to provide 14–20 kg of feed. Another aspect is the over consumption of water resources along the entire chain, from the irrigation of the crops, to the drinking water of the livestock (Delgado et al., 2008). Accordingly to Gerber et al. (2013) the breeding farms in the U.S.A. are responsible for 33% of the nitrogen and phosphorus pollution in drinking water, causing an increment of healthy issues in humans. Besides that, soil degradation and deforestation are other two reasons of generating valid concerns in the global population; as well as greenhouse gases emissions 9% of which is imputable to livestock production. Also, the 35–40% formation of methane is attributed to the farming activities.

However, among the environmental and ethical concerns just described, individuals who follow the vegan diet are vulnerable to the lacks of nutrients and microelements, such as proteins, zinc, calcium, iron, vitamin D, omega-3 fatty acids, iodine, vitamin B12. For example, vitamin B12 is found in fish, shellfish, meat and dairy products, and it stimulates many biochemical processes: formation of blood cells, activity of the nervous system and communication among neurotransmitters (Pollard et al., 2017). In addition, the situation can become very critical with the excessive consumption of fibers, especially in children. In April 2016, the first completely vegan and organic kindergarten opened in the city of Milan. On the other hand, doctors and psychotherapists claim that children required specific nutrients (Arginine an essential amino acid) in order to develop the cognitive system. So, it can be advisable, to introduce the vegan diet only after the three years of age.

Main vegan products

Eurispes (2017) described which are the main vegan products consumed in Italy: soups show a rise of the 37%, while second dishes incremented up to 27%; the so-called 'vegan milk' registered a raise of 19%.

The Court of Justice of the European Union emitted a sentence the 14th June 2017,[1] that completely pivoted the approach to the vegan food labelling. In fact, it declares that "*Purely plant-based products cannot, in principle, be marketed with designations such as 'milk', 'cream', 'butter', 'cheese' or 'yoghurt', which are reserved by EU law for animal products. The same is true if those designations are accompanied by clarifying or descriptive terms indicating the plant origin of the product concerned. However, there is a list of exceptions"*. It is likely that the most common ingredients of this way of eating are cereals, legumes, soybean, fruits and vegetables - both fresh and dried - hummus; besides, tofu, seitan, miso, seaweeds, sprouts, vegetal fatty acids and ready-to eat fresh or frozen foods which mimic the traditional characteristics of the animal-derived foods.

After the sentence just quoted, a dedicated chapter is required for the vegetal 'milks' so widely known nowadays; in fact, the denomination applied until then, infringed the regulation. This is why, from now on they will be nominated *'drinks with as the main ingredient…'*. Another field of research is related with the artificial development of the mycoproteins from *Fusarium venenatum* (Wiebe, 2004). The lab methodology implied the fermentation of the fungi in a glucose culture, at the temperature of 28–30 °C, and pH 6.0, for six weeks. This innovative ingredient has the goal to act as a substitute of the cell of the muscles, in animals; specifically, it should provide a fibrous texture to the food, with the result of a similar taste. In any case, the absence of a connective tissue (as for animals) implies the usage of a plasticizer: albumin is accepted for vegetarians but not for vegans. The Vegetarian Society has a specific list of food additives that are allowed in food products. In general, for the European Union food system, the Regulation (EC) No. 1333/2008 and the following Regulation (EU) No. 1169/2011 on food additives explain which are allowed in which food.

As for the vegan food products, one of the most common ingredient are the textured proteins, whose main component is soy. They are part of the vegan habits because they are rich in fibers, poor in fats, with no cholesterol and low energy content; moreover, they keep a rubbery aspect which imitates meat. Those proteins were initially developed in the U.S.A. where the United State Department of Agriculture (USDA) defined them as "a *processed food product manufactured from either soymeal flakes, soy flour, or soy protein concentrate. It can be uncoloured or caramel colour and contains at least 52 percent protein on a dry basis"* (USDA, 1971). During the process of extrusion, soy textured proteins assume the shape of flour (50–55% of proteins), concentrated proteins (65–70% of proteins) and isolated proteins (85–90% of proteins) (Yada, 2004; Riaz, 2001; Omwamba et al., 2014;). They can find different applications in the kitchen, even if they present a barrier for the consumer: an unpleasant odour, caused by isoflavonoids and saponin. New cultivars obtained with genetic engineering are being researched, to control the expression of the genes responsible for the off-flavour (Yada, 2004). Other fibers that can be extruded to obtain

[1] Court of Justice of the European Union PRESS RELEASE No 63/17. Luxemburg 14 June 2017. Judgement in Case C-422/16 Verband Sozialer Wettbewerb eV v TofuTown.com GmbH.

textured proteins are wheat, canola, cotton seeds, sunflower seeds, bean. The products achieved can be adopted with two main goals: firstly, as a complete substitute of meat; secondly – due to their technological characteristics – they find application as a cross-linker in traditional meat products (Riaz, 2006) Serdaroglu et al. (2005). emphasized that these types of textured proteins have gelling and emulsifier properties to reinforce the structural composition of minced meat. The very last news about vegan food comes from the Udine university (Italy) where vegan hard-boiled eggs were developed. This food has the characteristics of a traditional hard-boiled egg, but it is made entirely from plant-based ingredients, specifically various legumes, vegetable oils, a gelling agent and a vegan salt. The university granted the gluten- and cholesterol-free egg is patented.

Aim of the research

The aim of the present research was to develop adequate recipes to prepare food products that mimic the shape and the texture of traditional würstel and mortadella, still not available in the Italian market. Mortadella is defined by the Consorzio Mortadella Bologna I.G.P. as *"a deli meat, made entirely using pork meat, cylindrical or oval in shape, pink, with a strong smell, and lightly spiced"*. The German Food Guide defines Würstel as *"a long, thin sausage that is flavourful, lightly smoked, and made from pork"*. In the present research we wanted to mimic the palatability, texture and consistency of the traditional bagged products, but with ingredients suitable for vegans. Exclusively for this reason, we decided to nominate them as "mimic-mortadella" and "mimic-würstel", so to avoid confusion and misunderstanding.

Materials and methods

The tests were performed at laboratory scale at the University of Modena and Reggio Emilia, Department of Life Sciences. It was possible to implement and test the recipes so to find the most adequate.

The following Table 1 reports all the materials tested along the experimentation period:

These ingredients: salt, rice starch, grapeseed oil, chestnut flour, tofu, chickpea flour, wheat flour 00 and wheat gluten were purchase from local shops in Reggio Emilia (Italy).

"Mimic-würstel" and "mimic-mortadella" were prepared warming up the water at 60 °C, adding the gluten and other ingredients in the kneader, shaping the dough in a synthetic gut so to reproduce the shape of the traditional würstel and Mortadella. Then, they were steamed in the oven in two phases: 60 °C for 15 min; 100 °C for 20 min followed by an overnight refrigeration at 4 °C. The products obtained were stored refrigerated and vacuum packed for two days. Pork würstel, chicken würstel and Mortadella Bologna I.G.P. were bought from a local supermarket in Reggio Emilia (Italy) to compare the products under evaluation, with what already present in the market.

Brain Heart Infusion Agar (BHIA) (Biolife, Milan, Italy) and Reinforced Clostridial Agar (RCA) (Oxoid S.p.a., Milan, Italy) were used as growth media.

As for the microbiological evaluation, three serial dilutions in petri dishes with a diameter of 9 mm were prepared in BHIA for each of the five samples. The pH was measured with a pH meter (VWR, pH 110, Milan, Italy), then a sample of 10 g was transferred to a stomacher bag containing 90 mL of sterilized saline solution (0.9% NaCl) for one minute. One cm^3 of the last dilution was inoculated in triplicate sterile plates previously marked with the indication of the dilution (Pulvirenti et al., 2015). To create a thermal shock the samples were boiled for 10 min at 90 °C and then poured directly into petri dishes. Plates were incubated in anaerobic jars to prevent direct oxygen contact with cells, in a thermostated chamber at 30 °C for 24/48 h as reported by Pulvirenti et al. (2015).

The first load count was after 5 days in order to know if there would be any external contamination (ISO, 4833–1:2013); the second one. The second one was after 35 days because it is the commonly accepted period of shelf-life, expected for traditional Mortadella.

Regarding the sensory texture evaluation of both the "mimic-würstel" and the "mimic-mortadella, the vegan options were compared with the traditional foods. The texture was investigated with the help of a dynamometer (Bt1-fr1.0th.140 ZWICK/ROELL - Ulm, Germany). The values were weighted with the software TEXTEXPERT2 which elaborated an index of product consistency. The samples were prepared in cubes of 20 × 20 mm and analyzed both on the surface and in the inner central point.

Table 1
List of all the ingredients tested.

Ingredient name	Category	Provider
Modified corn starch	thickener	Saini srl
salt	seasoning, flavouring	Italkaly
Rice starch	thickener	Pedon, Italy
Guar gum seed flour	thickener, stabilizer	Myprotein
K-Carrageenan (CAS Number 9000-07-1)	thickener, stabilizer, gelling, emulsifier	Sigma-Aldrich
Methylcellulose (CAS Number 9004-67-5)	thickener, gelling	Sigma-Aldrich
Polyphosphates	thickener, stabilizer, gelling, emulsifier	Saini srl
Pectin	gelling	Herbstreith & Fox
Carob seed flour (87BIOLINE)	thickener, stabilizer, gelling, emulsifier	Bioline
Sucrose esters	emulsifier	Sisterna
Konjac	fiber	Myprotein
Bamboo (137BIOLINE)	fiber	Bioline
Pea functional fiber	fiber	Saini srl
Textured pea proteins	fiber	Nutralys®
Citric acid	acidity regulator, antioxidant	Saini srl
Sodium ascorbate (CAS Number 134-03-2)	acidity regulator, antioxidant	Sigma-Aldrich
Grape seed oil	antioxidant	Oleificio Zucchi, Italy
Meat aroma	natural aroma	Saini srl
Würstel aroma	natural aroma	Saini srl
Paprika aroma	natural aroma	Saini srl
Smocked aroma	natural aroma	Saini srl
Mortadella aroma	natural aroma	Saini srl
Tofu	substitute of fat globules	Valsoia
Chestnut flour	source of fiber, structuring	Molino Zanone, Italy
Bean proteins flour	source of fiber, structuring	Saini srl
Chickpea flour	source of fiber, structuring	Baule Volante, Italy
Wheat gluten	source of fiber, structuring	Tibiona, Italy
Wheat flour 00	structuring	Barilla

Results and discussions

"Mimic-würstel" and "mimic-mortadella" formulations

The main goal of this research was to realize two foods, traditionally prepared from meat: würstel and Mortadella, just with vegan ingredients. The property that "mimic-würstel" and "mimic-mortadella" need to show is the endurance after being cut in slices. We started to experiment recipes for "mimic-würstel".

The first recipe tested chestnut flour as the main ingredient, in addition with gelling agents, stabilizers and emulsifiers to support the framework and improve the final texture (see Appendix A – Table A1). The second tested chickpea flour (see Appendix A – Table A2). These two experiments did not show satisfactory outcomes. The third recipe included 92% of pea textured proteins, 0.9% of modified corn starch and 0.9% of rice starch (Appendix A – Table A3). The consistency obtained was very compact and rigid, which could easily arrive at the

breaking point. It was decided to add 8% of grape seed oil to the recipe, together with emulsifiers so to reduce the dimensions of the fats particles. The result was a "mimic-würstel" still extremely fibrous even if visually it was better (see Appendix A – Table A4). The following test verted more on the addition of grape seed oil 8% and methylcellulose 0.2% (see Appendix A – Table A5); then, grape seed oil 20% and methylcellulose 0.2% were added, so to achieve a "mimic-würstel" very similar to the traditional würstel (see Appendix A – Table A6). However, the obtained results were not satisfactory for the consumers requests and expectations.

Another recipe tested the Guar gum seed flour 3.3%, which did not show any significative improvement in the texture (see Appendix A – Table A7). Gluten proteins were added to the recipe, due to viscous and elastic properties when hydrated (see Appendix A – Table A8). The combination of ingredients with pea textured proteins as a base was considered the optimal solution: the consistency was analogous to the original products likewise the texture. The research of Kramer and Szczesniak (1973) was the base to understand how to cope with the analysis of texture.

Wheat gluten is one of the main components in foods not meat-based as reported by Day et al. (2006). For this reason, a recipe with the ratio between gluten and water 1:1 was tested; however, the relevant presence of Bamboo fiber (6.9%) provided the product too much consistency (see Appendix A – Table A9). Bamboo and its related properties have been recently examined due to the potential applications as functional food thanks to the antioxidants content. Especially in the case of bamboo fiber Chongtham et al. (2011), and Liu et al. (2012) reported that the products obtained by it are considered more environmental friendly and healthy; moreover, the presence of fibers aim to keep linked the ingredients of the recipe. The other combinations of ingredients tested are reported in the tables in Appendix A.

The two most successful recipes for the "mimic-würstel" are reported as follow in Tables 2 and 3.

The addition of wheat gluten brought a positive and meaningful result on the texture: the properties of viscosity and elasticity improved drastically. In the recipe with a ratio of 1: 2 between gluten and water the amount of fiber was strongly reduced, leaving the same level of k-carrageenan, including 1% of pectin. It has been demonstrated that the carrageenans own gelling and thickening properties, and their addition to food products enhance their textural characteristics. In particular Trius and Sebranek (1996), studied the effects of carrageenans on juiciness and toughness.

Then, the test with the ratio of 1: 3 was carried out (Tables 2 and 3). The validation of the recipe in Table 3 was successful after the texture evaluations mainly because the presence of fibers in the formulation ensures more health benefits, if compared to the presence of modified corn starch in the case of Table 2.

Thereafter, the preparation of "mimic-mortadella" was easier because it derived from the "mimic-würstel" in Table 3. Specifically, for "mimic-mortadella" cubes of tofu were added (Table 4). The presence of tofu of white colour mimic the effect of fat cells in traditional mortadella. During the cooking phase, it did not show any difficulty and it did not melt.

Table 2
Recipe with modified corn starch, smocked, meat and würstel aroma.

Ingredients	Quantity (g)	%
wheat gluten	258	23.4
water	705	63.9
k-carrageenan	60	5.4
modified corn starch	60	5.4
citric acid	15	1.4
smocked aroma	1	0.1
meat aroma	2	0.2
würstel aroma	3	0.3
total	1044	100

Table 3
Recipe with Bamboo fiber, smocked, meat and würstel aroma.

Ingredients	Quantity (g)	%
wheat gluten	258	20.4
water	840	66.4
k-carrageenan	60	4.7
bamboo fiber	87	6.9
citric acid	15	1.2
smocked aroma	1	0.1
meat aroma	2	0.2
würstel aroma	3	0.2
total	1266	100

Table 4
Recipe of "mimic-mortadella".

Ingredients	Quantity (g)	%
wheat gluten	258	17.0
water	840	55.4
k-carrageenan	60	4.0
bamboo fiber	87	5.7
citric acid	15	1.0
tofu	250	16.5
mortadella aroma	2	0.1
meat aroma	2	0.1
paprika aroma	1	0.1
total	1515	100

Microbiological evaluation

The microbiological analyses were carried out to determine the level of safety of the novel products; as mentioned above, the microbial load was counted after five days of incubation and after one month, for each of the five samples and their serial dilutions. The food safety of the "mimic-würstel" and "mimic-mortadella" was respected as in compliance with the food regulations, when compared to the traditional process meat-based products (Borch et al., 1996). In the sector of traditional salami production, the main microbiological challenges derive from the environmental conditions where the livestock grow, on one side; on the other side, they depend on where the feed is transformed and stocked. The bacterial contamination happens in fact after the slaughtering because the internal muscles of the animals are sterilized until that moment. To be more precise, the chemical and physical composition of animal muscles nurture the development and colonization of an elevate type of microorganisms, mostly bacteria; some of those are necessary for the fermentation and the aroma production, some of others are human pathogens. The parameters analyzed were: pH, humidity content, redox potential, level of nutrients, antimicrobial components, temperature during the storage period, concentration and typology of gases in the environment. Minced meat has always shown higher microbial load towards the entire muscle, because it is exposed to many different cuts and manipulations, augmented the surface of potential contamination and reproduction of *meso*phlic and aerobic bacteria (Regulation (EC). No 2073/2005).

Sensory texture evaluation

The resistance shown by the "mimic-mortadella" during the analysis was comparable to the one of the traditional mortadella as shown in Table 5. Conversely, the "mimic-würstel" registered values too high to be accepted (see Table 6), as reported by the Regulation (EC). No 2073/2005. The explanation can be found in the presence of wheat gluten: the dough obtained was compact and viscous.

The presence of the tofu cubes inside the "mimic-mortadella"

Table 5
Values of resistance in the vegan option and pork mortadella, expressed in Newton.

Sample	Average internal tensile strength (N)	Average tensile strength on the surface (N)
"mimic-mortadella"	7.29	9.67
pork mortadella	8.86	9.38

Table 6
Values of resistance in the vegan option, pork and chicken würstel, expressed in Newton.

Sample	Average internal tensile strength (N)	Average tensile strength on the surface (N)
"mimic-würstel"	16.21	18.51
pork würstel	6.66	9.05
chicken würstel	7.12	6.91

improved the performances during the cooking phase. Another aspect that should be taken into account is the dimension of the synthetic gut: for "mimic-mortadella" it was bigger allowing more homogenous cooking and emulsion; on the contrary, the smaller diameter of the "mimic-würstel" provoked a highest internal temperature during the cooking phase, so that the gluten proteins denatured. The internal resistance of the dough was higher than expected.

Conclusions

The challenge faced in this work was the ability to find the most suitable recipe for "mimic-würstel" and "mimic-mortadella". We firstly concentrated on the usage of different proteins as the basis to create a coherent structure, identifying the wheat gluten proteins as the best solution for two main reasons: they are accepted in vegan formulations and they help to preserve the elasticity, so typical of the traditional meat-based products. The "mimic-würstel" and "mimic-mortadella" we obtained are marketable in terms of texture and organoleptic properties and sensory texture evaluation. In conclusion, we can observe that the greatest challenge to face for vegan foods is to cope with the consumer's requests on one side; on the other, the substitution of animal proteins can generate issues in terms of shelf-life and expected texture.

Appendix A

See Tables A1–A13

Table A1
Recipe with chestnut flour.

Ingredients	Quantity (g)	%
chestnut flour	350	37
water	30	3.2
bean proteins flour	50	5.3
carob seed flour	5	0.5
k-carrageenan	7	0.7
modified corn starch	20	2.1
salt	30	3.2
citrus fiber	30	3.2
bamboo fiber	50	5.3
citric acid	5	0.5
sodium ascorbate	2	0.2
methylcellulose	50	5.3
grape seed oil	300	31.7
smocked aroma	3	0.3
meat aroma	10	1.1
würstel aroma	4	0.4
total	946	100

Table A2
Recipe with chickpea flour.

Ingredients	Quantity (g)	%
chickpea flour	350	38.3
water	30	3.3
bean proteins flour	50	5.5
Guar gum seed flour	2	0.2
k-carrageenan	28	3.1
modified corn starch	20	2.2
salt	30	3.3
citrus fiber	30	3.3
bamboo fiber	50	5.5
citric acid	5	0.5
sodium ascorbate	2	0.2
grape seed oil	300	32.8
smocked aroma	3	0.3
meat aroma	10	1.1
würstel aroma	4	0.4
total	914	100

Table A3
Recipe with textured pea proteins and bean proteins flour.

Ingredients	Quantity (g)	%
textured pea proteins	1000	92.3
bean proteins flour	20	1.8
modified corn starch	10	0.9
salt	20	1.8
rice starch	10	0.9
citric acid	5	0.5
sodium ascorbate	2	0.2
Konjac fiber	5	0.5
smocked aroma	1.5	0.1
meat aroma	5	0.5
würstel aroma	2	0.2
total	1083.5	100

Table A4
Recipe with textured pea proteins, bean proteins flour and grapeseed oil.

Ingredients	Quantity (g)	%
textured pea proteins	1000	80.0
bean proteins flour	40	3.2
modified corn starch	30	2.4
salt	20	1.6
rice starch	30	2.4
citric acid	5	0.4
sodium ascorbate	2	0.2
Konjac fiber	5	0.4
polyphosphates	5	0.4
grape seed oil	100	8.0
sucrose ester	5	0.4
smocked aroma	1.5	0.1
meat aroma	5	0.5
würstel aroma	2	0.2
total	1250.5	100

Table A5
Recipe with textured pea proteins, bean proteins flour, grapeseed oil (8%) and methylcellulose (2%).

Ingredients	Quantity (g)	%
textured pea proteins	1000	79.8
bean proteins flour	40	3.2
modified corn starch	30	2.4
salt	20	1.6
rice starch	30	2.4
citric acid	5	0.4
sodium ascorbate	2	0.2
Konjac fiber	5	0.4
polyphosphates	5	0.4
grape seed oil	100	8.0
methylcellulose	3	0.2
sucrose ester	5	0.4
smocked aroma	1.5	0.1
meat aroma	5	0.4
würstel aroma	2	0.2
total	1253.5	100

Table A6
Recipe with textured pea proteins, bean proteins flour, grapeseed oil (20.2%) and methylcellulose (0.2%).

Ingredients	Quantity (g)	%
textured pea proteins	1000	67.4
bean proteins flour	40	2.7
pea functional proteins	30	2.0
modified corn starch	30	2.0
salt	20	1.3
rice starch	30	2.0
citric acid	5	0.3
sodium ascorbate	2	0.1
Konjac fiber	5	0.3
polyphosphates	5	0.3
grape seed oil	300	20.2
methylcellulose	3	0.2
sucrose ester	5	0.3
smocked aroma	1.5	0.1
meat aroma	5	0.3
würstel aroma	2	0.1
total	1483.5	100

Table A7
Recipe with textured pea proteins, bean proteins flour, grapeseed oil (20.2%) and Guar gum seed flour (3.3%).

Ingredients	Quantity (g)	%
textured pea proteins	1000	66.9
bean proteins flour	40	2.7
modified corn starch	30	2.0
salt	20	1.3
rice starch	30	2.0
citric acid	5	0.3
sodium ascorbate	2	0.1
polyphosphates	5	0.3
grape seed oil	300	20.1
sucrose ester	5	0.3
Guar gum seed flour	50	3.3
smocked aroma	1.5	0.1
meat aroma	5	0.3
würstel aroma	2	0.1
total	1495.5	100

Table A8
Recipe with textured pea proteins, bean proteins flour, grapeseed oil (19.3%), Guar gum seed flour (0.3%) and wheat flour.

Ingredients	Quantity (g)	%
textured pea proteins	1000	64.5
bean proteins flour	40	2.6
modified corn starch	30	1.9
salt	20	1.3
rice starch	30	1.9
citric acid	5	0.3
sodium ascorbate	2	0.1
polyphosphates	5	0.3
grape seed oil	300	19.3
sucrose ester	5	0.3
Guar gum seed flour	5	0.3
wheat flour 00	100	6.4
smocked aroma	1.5	0.1
meat aroma	5	0.3
würstel aroma	2	0.1
total	1550.5	100

Table A9
Recipe with textured pea proteins, bean proteins flour, grapeseed oil (18.7%), Guar gum seed flour (0.3%), wheat flour and wheat gluten.

Ingredients	Quantity (g)	%
textured pea proteins	1000	62.3
bean proteins flour	40	2.5
modified corn starch	30	1.9
salt	30	1.9
rice starch	30	1.9
citric acid	5	0.3
sodium ascorbate	2	0.1
grape seed oil	300	18.7
sucrose ester	5	0.3
wheat gluten	50	3.1
Guar gum seed flour	5	0.3
wheat flour 00	100	6.2
smocked aroma	1.5	0.1
meat aroma	5	0.3
würstel aroma	2	0.1
total	1605.5	100

Table A10
Recipe with wheat gluten (23.6%) and grape seed oil (15.2%).

Ingredients	Quantity (g)	%
wheat gluten	233	23.6
water	550	55.7
modified corn starch	20	2.0
salt	10	1.0
grape seed oil	150	15.2
k-carrageenan	20	2.0
smocked aroma	1	0.1
meat aroma	2	0.2
würstel aroma	2	0.2
total	988	100

Table A11
Recipe with increased percentages of wheat gluten (33.9%) and grape seed oil (16.9%).

Ingredients	Quantity (g)	%
wheat gluten	300	33.9
water	350	39.5
modified corn starch	50	5.6
salt	10	1.1
grape seed oil	150	16.9
k-carrageenan	20	2.3
smocked aroma	1	0.1
meat aroma	2	0.2
würstel aroma	2	0.2
total	885	100

Table A12
Recipe with wheat gluten (32.0%) and bamboo fiber (6.9%).

Ingredients	Quantity (g)	%
wheat gluten	233	32.0
water	235	32.3
modified corn starch	20	2.7
salt	10	1.4
grape seed oil	150	20.6
k-carrageenan	20	2.7
bamboo fiber	50	6.9
citric acid	5	0.7
smocked aroma	1	0.1
meat aroma	2	0.3
würstel aroma	2	0.3
total	728	100

Table A13
Recipe with bamboo fiber (4.7%) and pectin (0.9%).

Ingredients	Quantity (g)	%
wheat gluten	233	22.1
water	550	52.2
modified corn starch	20	1.9
salt	10	0.9
grape seed oil	150	14.2
k-carrageenan	20	1.9
bamboo fiber	50	4.7
citric acid	5	0.5
pectin	10	0.9
smocked aroma	1	0.1
meat aroma	2	0.2
würstel aroma	2	0.2
total	1053	100

Table A14
Recipe with wheat gluten (18.5%), bamboo fiber (4.0%), rice flour (7.9%), wheat flour (7.9%).

Ingredients	Quantity (g)	%
wheat gluten	233	18.5
water	550	43.7
modified corn starch	20	1.6
salt	10	0.8
grape seed oil	150	11.9
k-carrageenan	20	1.6
rice flour	100	7.9
wheat flour 00	100	7.9
bamboo fiber	50	4.0
citric acid	10	0.8
pectin	10	0.8
smocked aroma	1	0.1
meat aroma	2	0.2
würstel aroma	2	0.2
total	1258	100

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