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A pre-competitive research on frozen *gnocchi*: quality evaluation and market survey

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ORIGINAL ARTICLE

Abstract

This research was aimed to evaluate quality and safety of five formulations of *gnocchi*, namely, traditional, tomato-basil, pumpkin, spinach, with cauliflower pieces, and stuffed with cheese, to be marketed in a frozen state. An online survey was performed to assess the consumer desires and willingness to buy these new products in order to assess consumer preferences and targets and verify whether fresh and frozen *gnocchi* could become market substitutes or complements. The results highlighted that frozen *gnocchi* were a good product under different points of view and characteristics of an ideal consumer.

Keywords: consumer preference; fresh pasta; online survey; quality; willingness to pay

Introduction

Gnocchi, a typical Italian dish prepared with potatoes, are widely known globally. This Italian name is derived from the term '*nocchio*', which refers to knots in wood, or from the term '*nocca*', which means 'knuckle'. Both these terms describe the classic shape of *gnocchi*. The preparation of the basic recipe is very simple, as it involves mixing and kneading of potatoes, previously boiled, peeled, and mashed with water, potato starch and flour (generally soft wheat, but sometimes rice flour, in the case of gluten-free products). Potato flakes can be used as an alternative to fresh potatoes. The obtained dough is then sectioned into small pieces of variable shapes and sizes. As for pasta, *gnocchi* are prepared by cooking in salted-boiling water and then dressed with various sauces depending on the type of g*nocchi* and recipe used. Cooking is very quick, and the optimal cooking point is the rise of *gnocchi* on the surface of the boiling water.

In the absence of a specific legislation, *gnocchi* are covered within the regulatory framework for fresh and stabilized pasta outlined by Law No. 580 of 1967 (Ministry of Agriculture, Food Sovereignty and Forestry, 1967), subsequently amended by DpR n. 187 of 2001 (Ministry of Agriculture, Food Sovereignty and Forestry, 2001) and DpR n. 41 of 2013 (Ministry of Agriculture, Food Sovereignty and Forestry, 2013).

In the past, *gnocchi* were mainly prepared at domestic and artisan levels whereas, nowadays, they are also produced at industrial level. The consumption of *gnocchi* is widespread in Italy, France and Germany, although markets, such as those of the United Kingdom, Spain and Eastern European countries, are also growing. Few data on the production and consumption of *gnocchi* are available. In 2013, Italy produced 11,5000 tons of *gnocchi* against 27,000 tons in France, and exported almost half of its production (Storchi, 2014). The Italian production of packaged *gnocchi* is constantly growing, passing from €65 million to over €165 million in 1995–2017. In 2017, 20% of Italian *gnocchi* were exported to extra-EU countries for sale on the shelves, as the product is stable at room temperature. The remaining 80% of exports comprised

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refrigerated product, which was done to European markets (Bonetto, 2018).

Owing to its small size, the market of *gnocchi* has interesting growth margins because of product and process innovation. According to the available statistical reports (Expert Market Research, 2022), the global market of *gnocchi* is driven by the growing requirement of convenience foods and is expected to further increase in 2022–2027 at a compound annual growth rate (CAGR) of 4.50%, particularly in North America, Europe, the Asia Pacific, Latin America, the Middle East and Africa.

In addition, according to the *gnocchi* regulatory framework, producers are free to modify shapes and ingredients, thus creating a variety of formulations. Considering that the current sale channels are essentially limited to fresh *gnocchi* (prepared for consumption within a few hours of production), refrigerated product (with a shelf life of 80–120 days, reduced to 60 days in the case of stuffed *gnocchi*, at temperatures of 4–8° C), and stable product at room temperature (shelf life of 180 day in a cool and dry place), an interesting market niche to explore is that of frozen product, which would allow a further extension of shelf life in the absence of preservatives. In fact, *gnocchi* are currently sold in a frozen state almost exclusively as ready-to-eat meals or as a semi-finished product to companies that deal in ready-to-eat meals.

Innovation must be accompanied with a careful control of the effects of product/process changes made on the safety and quality characteristics of new products as well as on consumer demands. The safety of *gnocchi* is generally related to its microbial population (Chunfeng *et al*. 2005; Del Torre *et al*., 2004), while their quality is strongly related to their physico-chemical (mainly water activity [a_w], texture and pH), nutritional, and sensory properties (Alessandrini *et al*., 2010; Bercot *et al*., 2014; Liu *et al*., 2016).

In addition, studies on consumer preferences and willingness to buy/pay are useful tools to forecast the success of any product on market (Barcelon *et al*., 2014; Defrancesco *et al*., 2017). Previous studies on innovation arrived at in *gnocchi* production generally referred to changes in some ingredients and their effects of product's quality. In this context, it is worth mentioning the addition of orange-fleshed sweet potato (da Silva *et al*., 2016), mix of tilapia and tuna (Coradini *et al*., 2019), sea water (Santagata *et al*., 2021), red rice, or buckwheat (Cappa *et al*., 2021). Process innovation was less considered: an example was the production of frozen gluten-free *gnocchi* through turbo cooking (Cappa *et al*., 2017).

The present research aimed to evaluate quality and safety of new formulations of *gnocchi* that can be marketed in a frozen state. Successively, an online survey was performed to assess the consumer desire and willingness to buy new products. More than 500 interviews were conducted, and a *gnocchi* preferences database was set up for analysis. The purpose of this market analysis was to verify whether frozen *gnocchi* could be substituted for other types of *gnocchi*, and whether frozen *gnocchi* had the same target. The research also focussed on both traditional and flavoured *gnocchi* to verify whether consumer desire and willingness to buy frozen version are affected by the presence of other ingredients in the formulations. The analysis was carried out by hypothesizing a system of simultaneous equations of *gnocchi* purchase behaviour, in which consumers are willing to purchase different types of frozen *gnocchi*.

Materials and Methods

Gnocchi production

Six types of *gnocchi* were considered: traditional *gnocchi*; tomato-basil *gnocchi*; pumpkin *gnocchi*; spinach *gnocchi*; *gnocchi* with cauliflower pieces; and cheese-stuffed *gnocchi*. Owing to their formulations, all types of *gnocchi*, except those stuffed with cheese, were gluten-free. For each formulation, a preliminary work was carried out to develop the best recipe, considering both production of dough capable of mechanical formulation and ability to meet the needs of a wide range of consumers by avoiding strong tastes, application of preservatives, and using ingredients referred to the Mediterranean diet. The optimized formulations are reported in Table 1.

Production was carried out in an industrial plant located in Apulia region (Southern Italy). According to the production process, hot water, flour and other ingredients were mixed and kneaded (Condor PPS 130, San Giovanni Lupatoto, Italy). Successively, the dough was transferred to forming machine (M-Agnelli A/250, Bussero, Italy). In the case of cheese-stuffed *gnocchi*, formulation was combined with cheese extrusion (Sandore NF 80, Zanè, Italy). *Gnocchi* were then transported to freezing tunnel (Pugnale, Milano, Italy) by a conveyor belt (Bonfiglioli BN63B4, Bologna, Italy) where products achieved a temperature of -18°C within 7 min.

Three batches, each of about 100 kg, were produced for each type of *gnocchi*. The weight of each dumpling was 3.5±0.3 g.

Sampling

For sampling, five aliquots, each of 500 g, were taken from each batch. Each aliquot was submitted to physical, chemical, and microbiological analyses.

Table 1. Formulations of *gnocchi*.

Ingredients (%)	Types of *gnocchi*					
	Traditional	Tomato-basil	Pumpkin	Spinach	with Cauliflowers	Stuffed with cheese
Water	52	50	50	52	20	50
Cauliflower	–	–	–	–	40	–
Wheat flour	–	–	–	–	–	30
Corn flour	14	–	–	–	–	–
Potato flakes	13	10	15	15	–	8
Potato starch	14	18	18	18	23	11
Corn starch	6	14	14	13	–	–
Tapioca	–	–	–	–	16	–
Salt	1	2	1	1	1	0.93
Tomato	–	3	–	–	–	–
Basil	–	2	–	–	–	–
Pumpkin	–	–	1	–	–	–
Spinach	–	–	–	1	–	–
Safflower	–	–	–	–	–	0.07
Turmeric	–	–	1	–	–	–
Paprika	–	1	–	–	–	–

Physical and chemical analyses

Gnocchi samples were submitted to the following analyses immediately after freezing:

- Moisture content, expressed as moisture percentage, measured through a thermo balance (Sartorius MA35M-230N, Goettingen, Germania) at 130°C until a constant weight was reached.
- Water activity, a_w, determined by using a Testo 650 Water Activity System (Testo, Milan, Italy).
- pH, through a SI Analytics Lab845 pH-meter (Wheilheim, Germany).

All analyses were repeated for at least five times for each aliquot.

Microbiological analyses

Firstly, immediately after preparation, all types of *gnocchi* were examined. For this, 10 g of *gnocchi* was withdrawn from each aliquot, diluted with 90 g of buffered peptone water and homogenized for 2 min in a Stomacher Lab Blender Model 400 (Seward Medical, England). Decimal dilutions (from 10^{-1} to 10^{-6}) were prepared and 0.1 mL of each dilution was spread on the surface of the following medium supplied by HyServe GmbH & Co. KG (Uffing, Germany):

- Plates of compact dry total count, and incubated at 30°C for 48 h to enumerate total aerobic bacteria (ISO 4833-1; International Organization for Standardization (ISO), 2013).
- Plates of compact dry total coliforms, and incubated at 37°C for 24 h to enumerate total coliforms (ISO 4832; ISO, 2006).
- Plates of compact dry yeasts and moulds, and incubated at 30°C for 72 h to quantify yeasts and moulds (ISO 21527-2; ISO, 2008).

In order to evaluate the evolution of microbiological quality of *gnocchi* under different storage conditions, additional analyses were performed on three of the new formulations, namely, traditional *gnocchi*, *gnocchi* with cauliflower pieces and cheese-stuffed *gnocchi*, because of their consumer target, not homogeneous (inhomogeneous) structure, and animal origin, respectively. Such analyses were performed on samples stored under the following time–temperature pairs: just frozen *gnocchi*, 0 day/–18±2°C (T0); and the following thermal abuse conditions: 40 days/–12±2°C (T1), 10 days/–6±2°C (T2) and 2 days/8±2°C (T3). *Gnocchi* were analysed for total aerobic bacteria (ISO 4833-1; ISO, 2013), total coliforms (ISO 4832; ISO. 2006), sulphite-reducing clostridia (ISO 15213; ISO, 2003), coagulase-positive staphylococci (UNI EN ISO 6888-1; UNI Italian Standardization, 2018), yeasts and moulds (ISO 21527-2; ISO, 2008), *Escherichia coli* (ISO 16649-2; ISO, 2001), *Listeria monocytogenes* (ISO 11290-1; ISO, 2017a), *salmonella* ssp. (ISO 6579-1; ISO, 2017b), and *Bacillus cereus* (MI 016/12 rev. 2; Google.it, 2013). In addition, traditional *gnocchi* were also analysed for *salmonella* ssp. (ISO 6579-1; ISO, 2017) whereas *gnocchi* with with cauliflower pieces and

cheese-stuffed *gnocchi* samples were also analysed for *pseudomonas* ssp. (ISO/TS 11059; ISO, 2009b).

The analyses were performed in duplicate for each aliquot, and the results were expressed as CFU/g.

Nutritional analysis

The proximate analysis of just-frozen traditional *gnocchi*, *gnocchi* with cauliflower pieces and cheese-stuffed *gnocchi* was performed. The following parameters, expressed per 100 g of *gnocchi* were evaluated: energy (as KJ and Kcal; EU Reg 1169; European Union [EU], 2011); carbohydrate, total fats and saturated fatty acids (in grams; ISTISAN 34; Istituto Superiore Di Sanita [ISTISAN], 1996); proteins (in grams, ISO 1871; ISO, 2009a); fibre (in grams; ISO 5498; ISO, 1981); sodium chloride (in grams; MI 019/14 rev 3, 2017 and EU Reg. N. 1169; European Union, 2011), moisture (as %; ISTISAN 34; ISTISAN, 1996), and ash (in grams; UNI EN ISO 2171; UNI Italian Standardization, 2010). On cauliflower samples, the following additional analyses were performed: calcium, iron, potassium (as mg/kg; ISO 21424; ISO, 2018b), vitamin A (as µg/100 g; ISTISAN 34; ISTISAN, 1996), vitamin C (as mg/100 g; ISTISAN 34; ISTISAN, 1996), and vitamin D (µg/100 g; ISO 20636; ISO, 2018a). The analyses were performed in duplicate for each aliquot.

Sensory analysis

The sensory evaluation of traditional *gnocchi*, *gnocchi* with cauliflower pieces, and cheese-stuffed *gnocchi* was performed by a panel consisting of 11 highly trained judges (with >100 h of descriptive training and >1000 h of testing experience). *Gnocchi* samples were cooked in unsalted boiling water. Two cooking periods were considered: the period corresponding to the emersion of *gnocchi* on water surface (optimal cooking time), and the period obtained by prolonging cooking for another 20 s to evaluate the effects of overcooking. Panellists were asked to evaluate five parameters, namely, visual appearance, odour, taste, texture and stickiness, on a 5-point scale (from 0 to 4, with 2.5 as the lower limit for considering the product as acceptable) anchored with extremely low and extremely high parameters related to the perception of stimuli. The sensory procedures were replicated thrice. Samples were coded with random 3-digit numbers and served monodically. To balance out any possible order-effect, the order of presentation was randomized for each panellist and each session, and the samples were evaluated using a completely randomized design. In order to reduce carry-over effects, a 1-min break was provided between samples, during which panellists were required to rinse their mouths thoroughly with spring water. The sensory sessions were conducted in a sensory room equipped with eight booths according to the ISO standard 8589 (ISO, 2007). The temperature was kept at 24±2°C. Humidity was in the range of 70–85%.

Market survey

A survey of six *gnocchi* formulations (traditional, tomato-basil, pumpkin, spinach, with cauliflower pieces, and cheese-stuffed) was conducted on the Italian market. A questionnaire comprising 19 questions was prepared and distributed through an open access online document that gathered 532 responses. The first part of the questionnaire contained 11 detailed questions on socio-demographic characteristics of respondents and family components (place of residence, age, gender, education level, employment, household composition, household income, and food expenditure). The remaining eight questions concerned food habits and methods of choice of *gnocchi* (frequency of consumption, preferred types of *gnocchi* in terms of formulation, packaging and storage, and selling prices). The questionnaire was structured with open, closed, and multiple-choice questions as well as with preference lists and scales. The survey was conducted online on a convenience sample. The sampling strategy followed the snow-ball effect strategy by multiple sharing of the link on messaging app and social media.

Statistical analysis

Mean values and standard deviations were calculated using the Excel software V. 14.0.0 for Mac. The analysis of variance (ANOVA) of the experimental data was performed using the statistical package Statistica for Windows V. 8.0. (Statsoft Inc., Tulsa, OK). ANOVA and the Tukey HSD test ($p < 0.05$) were applied to determine statistically significant differences among samples.

Concerning the market survey, first the respondent characteristics were analysed using descriptive statistics. Then, an econometric model was set up to estimate the impact of the following: socio-demographic variables of respondents, their food consumption habits, and respondents' declared preferences about *gnocchi* for the price they were willing to pay. The econometric strategy was based on a system of simultaneous equations, in which each model represented a certain type of *gnocchi* considered for analysis. The strategy was coherent with the choice context of specific product, as one could choose at the same time to buy one or more types of *gnocchi:*

$$P_{ij} = f(Z_i, H_i, R_i), \quad (1)$$

where

P is the price that the ith consumer is explicitly willing to pay for the jth type of *gnocchi*;
Z is the socio-demographic characteristics of the ith consumer;
H is the food consumption habits of the ith consumer;
R is the general preferences about *gnocchi* of the ith consumer.

For the estimation of the model, STATA 14.0 was used to run a Seemingly, Unrelated, REgression (SURE) method developed by Zellner (1992). The method allowed estimating more models simultaneously and considering model error dependence. Such a need, which was not considered in standard regression model, was linked to the simultaneity of the choice, and in our case to the simultaneity of the purchase of different types of *gnocchi*.

Results and Discussion

Physico-chemical characteristics of optimized formulations

As shown in Table 2, the lowest moisture content was found in cheese-stuffed samples of *gnocchi.* The dough of this sample had added water comparable with those of other formulations (with the exception of *gnocchi* with pieces of cauliflower) and had a cheese filling having a water content of around 37% and representing 20% of the total mass of the product. The highest percentage of moisture was estimated in *gnocchi* with pieces of cauliflower, whose formulation consistently differed from those of other samples. In fact, although the amount of added water was significantly lower than that of other formulations, a higher water intake derived from cauliflower (around 92–94%) and the amount of dry ingredients was lower than that in other formulations.

Water activity is a suitable tool for predicting the growth of microorganisms. The average water activity values (Table 2) were in the range established by DpR n. 187 (Ministry of Agriculture, Food Sovereignty and Forestry, 2001) for fresh pasta ($0.92 \geq a_w \geq 0.97$), with the exception of those referred to traditional *gnocchi*, in which water activity was slightly lower but above the limit value required for the growth of selected pathogens (0.85; Food and Drug Administration (FDA), 2011.

As can be inferred from data, moisture content and water activity values were not correlated. In particular, traditional *gnocch*i had one of the higher moisture contents and the lowest water activity. Their formulation strongly differed from other samples for their high content of corn flour, known for its high sorption capacity (Ahmed and Islam, 2018), which is, in turn, related to lower amylose content (around 29%), compared with those with potato starch (~54%) and tapioca (36%) (Horstmann *et al*., 2016). In agreement with Biduski *et al*. (2018), starch samples with high amylose content have lower water absorption because of the greater stiffness of hydrogel structure that resists swelling.

The average pH (Table 2) was in the range 4.62–5.95, with the lowest value detected in tomato-basil *gnocchi* because of the acids contained in characterizing ingredients, and the highest pH measured in cheese-stuffed *gnocchi* mainly because of the contribution of the stuffed ingredient. All the samples showed pH values above the lower limit required for the growth of pathogens; however, because of the temperature range required for growth of pathogen, freezing guaranteed to limit their development (Food and Drug Administration [FDA], 2019).

Microbiological profiles of *gnocchi*

In spite of *gnocchi* being an excellent growth substrate for microorganisms, especially in the case of storage under improper conditions, this was the first study to include a comprehensive microbiological characterization of *gnocchi*. In fact, previous studies were limited to the enumeration of total bacteria and moulds during refrigerated storage and the growth and survival of specific microorganisms, such as *Listeria monocytogenes* or *Staphylococccus aureus* (Hu *et al*., 2017; Szymczak and Dąbrowski, 2015; Wu *et al*., 2018).

Table 2. Physico-chemical characteristics of *gnocchi*.

Parameters	Types of *gnocchi*					
	Traditional	Tomato-basil	Pumpkin	Spinach	with Cauliflowers	Stuffed with cheese
Moisture (%)	55.7±0.6^{b,c}	50.6±2.3^{b}	52.1±3.1^{b,c}	50.7±3.6^{b}	56.7±1.2^{c}	44.2±0.3^{a}
a_w	0.90±0.01^{a}	0.92±0.01^{a,b}	0.93±0.01^{b}	0.92±0.02^{a,b}	0.93±0.01^{b}	0.95±0.01^{c}
pH	5.10±0.11^{b}	4.62±0.22^{a}	5.40±0.10^{c}	5.42±0.09^{c}	5.72±0.11^{d}	5.95±0.12^{e}

Different letters indicate significant differences among types of *gnocchi* (Tukey test, $p < 0.05$).

Regarding the microbial profiles of just prepared *gnocchi*, the formulation containing pieces of cauliflower showed the highest mesophilic load (together with those stuffed with cheese) and total coliforms (Table 3). According to the collected data, a modification to washing procedures was suggested in the case of *gnocchi* with cauliflower. Owing to the peculiar conformation of cauliflower inflorescence, water was difficult to reach its various parts, hence a washing extension and/or the use of floating water could be useful to improve its hygienic quality. Traditional *gnocchi* generally showed the lowest microbial load, although their total aerobic bacteria were 1 logarithmic cycle higher than those detected by Hu *et al*. (2017). The presence of yeasts and moulds was negligible in all the samples.

In order to better understand the evolution of microbial profile under specific storage conditions, additional analyses were performed on traditional *gnocchi*, *gnocchi* with cauliflower pieces, and cheese-stuffed *gnocchi*; the results are reported in Table 4. Individual and interactive effects of the type of *gnocchi* and the storage conditions on the concentration of various microbial groups were analysed. Results showed that pathogens were below the detection limit in all the samples to prove product's safety and compliance with the safety criteria established by EU Reg. N. 1441 (European Union, 2007), which relates to the microbiological criteria applicable to food products. Surveys performed by other researchers highlighted the presence of *Listeria monocytogenes* in refrigerated shrimp salads-contained *gnocchi* (Burnett *et al*., 2005). However, a high presence of moulds and yeasts was detected in traditional *gnocchi* whereas a high total bacterial load and occurrence of *Pseudomonas* spp. were observed in cheese-stuffed *gnocchi*. Concerning the effects of storage conditions, the combination T1 (40 days/−12±2 °C) was the most disadvantageous conditions for total bacterial load and occurrence of yeasts and *Pseudomonas* spp., while the combination T2 resulted in a greater presence of total coliforms. Concerning the interactive effects of the type of *gnocchi* and the storage conditions, those stuffed with cheese and subjected to T1 storage conditions showed the highest levels of total bacterial load, yeasts, and *Pseudomonas* spp., while those subjected to T2 storage conditions had the highest concentration of total coliforms. These data were in agreement with the literature, as some strains, such as *Pseudomonas fragii*, grow at temperatures as low as −6°C and *Pseudomonas fluorescens* grow at temperatures as low as −4°C (Feiner, 2006). These data highlighted the detrimental effects of storage temperatures higher than −18°C.

In any case, based on the Recommendation No. 011 issued by the Italian Frozen Food Institute (IIAS, 2006), which provides useful information for determining minimum storage period for frozen food marketed in Italy, the experimental *gnocchi* could be labelled with a shelf-life of 18 months if stored under freezing conditions.

Nutritional value of *gnocchi*

Based on the nutritional information (Table 5), *gnocchi* were low in calories, supplying from 141 Kcal/100 g (*gnocchi* with pieces of cauliflower) to 185 Kcal/100 g (cheese-stuffed *gnocchi*). Obviously, these products are intended to represent the first course, providing high intake of carbohydrate but small amounts of proteins and lipids (just a little more in cheese-stuffed *gnocchi*). As a result, they had a medium glycemic index (around 68; Johnson-Greene, 2020). *Gnocchi* with cauliflower pieces had a good mineral content contributed by fresh vegetable, while the intake of both fat- and water-soluble vitamins was negligible. The sodium/NaCl content of cheese-stuffed *gnocchi* was almost double, compared with the other two types of *gnocchi*. probably because, beyond the salt added to the formulation, more sodium comes from the other ingredients used in the production of the gnocchi. The goal of reducing salt intake is pursued globally by all institutions dealing with public health. For example, according to the 'Salt Reduction Targets for 2017' published by the Public Health England (PHE, 2017), pasta should contain no more that 0.88-g salt or 350-mg sodium, 0.5-g salt per 100 g. In this perspective, the experimental *gnocchi* must be labelled with the recommendation of not adding salt to the cooking water with only limited amount of seasoning.

Table 3. Microbial loads (CFU/g) of just prepared *gnocchi*.

Microorganisms	Types of gnocchi					
	Traditional	Tomato-basil	Pumpkin	Spinach	with Cauliflowers	Stuffed with cheese
Total aerobic bacteria	6×10^{3a}	3.8×10^{4c}	1.6×10^{4b}	1×10^{4b}	$4.2\times10^{4c,d}$	4.9×10^{4d}
Total coliforms	6.3×10^{2a}	1×10^{3b}	5.5×10^{2a}	6.6×10^{2a}	2.6×10^{3c}	7.7×10^{2a}
Yeasts	10^{2a}	3×10^{2b}	$4\times10^{2b,c}$	10^{2a}	5×10^{2c}	3×10^{2b}
Moulds	10^{2a}	10^{2a}	10^{2a}	10^{2a}	$<10^{2a}$	10^{2a}

Different letters indicate significant differences among types of *gnocchi* (Tukey test, $p < 0.05$).

Table 4. Microbial loads (CFU/g) of *gnocchi* stored in different conditions.

Microorganisms	*Gnocchi*	T0 (0 days; –18°C)	T1 (40 days; –12±2°C)	T2 (10 days; –6±2°C)	T3 (2 days; 8±2°C)
Total aerobic bacteria	Traditional	1.3×10^2	2×10^2	5.3×10^2	5.8×10^3
	Cauliflower pieces	4.4×10^2	8×10^3	6.5×10^3	2.2×10^3
	Stuffed with cheese	1.6×10^4	1.2×10^5	10^5	9.6×10^4
Total coliforms	Traditional	<10	<10	<10	<10
	Cauliflower pieces	$<10^2$	6×10^2	5×10^2	6×10^2
	Stuffed with cheese	1.6×10^2	10^3	1.6×10^3	1.2×10^3
Yeasts	Traditional	$<4\times10^2$	$<4\times10^2$	$<4\times10^2$	$<6\times10^2$
	Cauliflower pieces	$<10^2$	$<4\times10^2$	$<4\times10^2$	$<10^2$
	Stuffed with cheese	$<10^2$	$<10^2$	$<10^2$	$<10^2$
Moulds	Traditional	8×10^3	2.6×10^3	$<10^2$	3×10^3
	Cauliflower pieces	$<10^2$	$< 4\times10^2$	$<10^2$	$<10^2$
	Stuffed with cheese	$<10^2$	$<10^2$	$<10^2$	$<10^2$
Salmonella spp.	Traditional	Absent in 25 g	Absent in 25 g	Absent in 25 g	Absent in 25 g
	Cauliflower pieces	n.d.	n.d.	n.d.	n.d.
	Stuffed with cheese	n.d.	n.d.	n.d.	n.d.
Escherichia coli	Traditional	<10	<10	<10	<10
	Cauliflower pieces	<10	<10	<10	<10
	Stuffed with cheese	<10	<10	<10	<10
Listeria monocytogenes	Traditional	Absent in 25 g	Absent in 25 g	Absent in 25 g	Absent in 25 g
	Cauliflower pieces	Absent in 25 g	Absent in 25 g	Absent in 25 g	Absent in 25 g
	Stuffed with cheese	Absent in 25 g	Absent in 25 g	Absent in 25 g	Absent in 25 g
Bacillus cereus	Traditional	$<10^2$	$<10^2$	$<10^2$	$<10^2$
	Cauliflower pieces	$<10^2$	$<10^2$	$<10^2$	$<10^2$
	Stuffed with cheese	$<10^2$	$<10^2$	$<10^2$	$<10^2$
Coagulase+staphylococci	Traditional	$<10^2$	$<10^2$	$<10^2$	$<10^2$
	Cauliflower pieces	$<10^2$	$<10^2$	$<10^2$	$<10^2$
	Stuffed with cheese	$<10^2$	$<10^2$	$<10^2$	$<10^2$
Sulphite-reducing clostridia	Traditional	<10	<10	<10	<10
	Cauliflower pieces	<10	<10	<10	<10
	Stuffed with cheese	<10	<10	<10	<10
Pseudomonas spp.	Traditional	n.d.	n.d.	n.d.	n.d.
	Cauliflower pieces	$<10^2$	3.6×10^3	6×10^2	$<4\times10^2$
	Stuffed with cheese	3×10^3	3.1×10^4	2×10^4	10^4

n.d.: not determined.

Sensory evaluation of *gnocchi*

The results of sensory evaluations (Table 6) highlighted that all the parameters were evaluated as more than acceptable. The highest scores were generally assigned to sample odour. The extension of cooking period exerted negative effects on taste and, in higher extents, on texture and stickiness that sometimes were considered less than acceptable. Cheese-stuffed *gnocchi* received significantly higher scores for taste, texture, and stickiness, probably because of the presence of wheat flour in their formulations and the consequent formation of a gluten network that was able to improve their textural properties.

Online survey: profiles, behaviors and attitudes of respondents

Table 7 describes the profile of participants of online survey. Most of the respondents were males (60%) in the age groups of 18–30 years (56%), 31–40 years (10%),

Table 5. Nutritional information on *gnocchi*.

	Types of gnocchi		
	Traditional	with Cauliflowers	Stuffed with cheese
Energy			
KJ	645[a]	598[a]	785[b]
KCal	152[a]	141[a]	185[b]
Carbohydrates	34.71[b]	31.60[a]	36.76[c]
Sugars	0.06[b]	<LQ[a]	0.92[c]
Fructose			
Glucose	0.07[a]	0.13[b]	0.68[c]
Lactose	<LQ[a]	<LQ[a]	<LQ[a]
Maltose	0.07[a]	0.07[a]	4.18[b]
Saccharose	<LQ[a]	<LQ[a]	<LQ[a]
Fats	0.23[a]	0.47[b]	0.95[c]
Saturated fatty acids	<0.10[a]	<0.10[a]	0.32[b]
Fiber	2.02[b]	2.02[b]	1.06[a]
Proteins	1.79[a]	1.61[a]	6.87[b]
Sodium	0.72[a]	0.72[a]	1.11[b]
NaCl	1.40[a]	1.79[b]	2.77[c]
Ash	1.76[a]	1.85[a]	3.14[b]
Minerals			
Ca	n.d.	332.71	n.d.
Fe	n.d.	2.31	n.d.
K	n.d.	1016.33	n.d.
Vitamins			
A	n.d.	<0.5	n.d.
C	n.d.	<LQ	n.d.
D	n.d.	<0.5	n.d.

Different letters indicate significant differences among types of *gnocchi* (Tukey test, $p < 0.05$).
LQ: quantification limit. The values are expressed in g/100 g, with the exception of those referred to Ca, Fe, and K, which are expressed in mg/kg, and those referred to vitamins A, C, and D, expressed in µg/100 g, mg/100 g, and µg/100 g, respectively. n.d.: not determined.

41–50 years (20%) and 51–60 years (11%). The education level of the participants was high, since about 18% stated to have a specialization or a PhD, and 44% declared to be graduates (with bachelor's or master's degree).

Concerning employment, about 58% of respondents stated to have a job, while 10% were unemployed. The number of student respondents was also significant (~28%). In all, 237 of the 532 respondents indicated their specific occupation. The respondents mainly comprised employees (22%), freelancers (14%), teachers (11%), university professors (10%), catering operators (6%), entrepreneurs (5%), workers (5%), and those employed in the food quality control sector (5%).

Concerning the family size, 38% of participants' families consisted of four individuals, while around 3% stated as having a larger family (>5 members). The incidence of families comprising one or two persons (~11% and 18%, respectively) was interesting. The average number of family members was 3.3.

Concerning the place of residence, most of the respondents were urbanites, with ~43% residing in cities of 50,001–200,000 inhabitants, or in a town with 5000–20,000 inhabitants (~33%).

Regarding the geographical origin of participants, most of them lived in Puglia (73.3%) and Lombardia (10.5%), followed by Emilia-Romagna (2.6%), Lazio and Piemonte (2.4%), Abruzzo (1.9%), Toscana (1.7%), Veneto (1.3%), Campania (0.9%), Basilicata (0.8%), Marche (0.6%), Sicilia (0.4%), and Calabria, Molise, Liguria, Sardegna, Trentino-Alto-Adige, and Umbria (0.2% each).

The gross annual income of respondents was €15,000–28,000 (~40%) and €28,000–55,000 (~27%); 46% of the respondents spent €50–100 on food per week.

Most of the respondents were involved in food purchase, but with some differences: 19.4% of the respondents were

Table 6. Results of sensory analysis.

Types of *gnocchi*	Visual appearance		Odour		Taste		Texture		Stickiness	
	C.T.	C.T.+20 s	C.T.	C.T.+20 s	C.T.	C.T.+20 s	C.T.	C.T.+20 s	C.T.	C.T.+20 s
Traditional	3.8±0.8^{a,A}	3.4±0.7^{a,A}	3.9±0.6^{a,A}	3.7±0.7^{a,A}	3.7±0.5^{b,A}	3.1±0.5^{a,A}	3.5±0.5^{b,A}	2.8±0.5^{a,A}	3.1±0.4^{b,A}	2.7±0.5^{a,A}
With cauliflower pieces	3.5±0.7^{a,A}	3.1±0.7^{a,A}	3.8±0.4^{a,A}	3.7±0.5^{a,A}	3.7±0.6^{b,A}	3.2±0.4^{a,A}	3.4±0.5^{b,A}	2.7±0.5^{a,A}	3.1±0.3^{b,A}	2.6±0.5^{a,A}
Stuffed with cheese	3.5±0.8^{a,A}	3.4±0.7^{a,A}	3.9±0.5^{a,A}	3.7±0.5^{a,A}	4.0±0^{b,B}	3.7±0.2^{a,B}	3.7±0.6^{b,A}	3.1±0.7^{a,B}	3.2±0.4^{b,A}	2.9±0.5^{a,B}

Different lowercase letters indicate significant differences among the cooking times (Tukey test, $p < 0.05$).
Different uppercase letters indicate significant differences among types of *gnocchi* (Tukey test, $p < 0.05$).

Table 7. Profile of respondents (n = 532).

Variable	%
Gender	
Males	60.0
Females	40.0
Age (years)	
18–30	55.8
31–40	9.6
41–50	20.3
51–60	10.9
61–70	2.4
71–80	0.6
>80	0.4
Education level	
Compulsory school	4.9
High school diploma	33.4
Bachelor's degree	19.0
Master's degree	25.0
Specialization/PhD	17.7
Occupation	
Student	27.6
Housewife	2.6
Employed	57.7
Retired	2.1
Unemployed	10.0
Number of family members	
1	10.7
2	18.2
3	17.5
4	37.8
5	13.0
>5	2.8
Number of inhabitants of the city in which the respondent lives	
<5000	2.4
5000–20,000	32.9
20,001–50,000	10.6
50,001–20,0000	43.2
200,001–500,000	6.8
>500,000	4.1
Gross annual household income (€)	
0–15,000	20.5
15,001–28,000	40.2
28,001–55,000	27.5
55,001–75,000	7.1
>75,000	4.7
Average weekly expenditure on food purchases (€)	
<50	19.4
50–100	46.4
101–150	21.0
151–200	6.6
>200	1.9
He/she doesn't know	4.7
Who makes food purchases in the respondent family	
Only the respondent	19.4
The respondent but also other family members	67.9
The respondent but only upon instructions of other family members	8.4
The respondent doesn't make food purchases in his/her family	4.3
Presence of any food intolerance, unwelcomed foods, and digestion difficulties in the respondent family	
Yes	67.1
No	32.3
No reply	0.6

the only family member to make food purchase; 67.9% of them alternated with other members; 8.5% indulged in making purchases if instructed by other family members; and only 4.3% never indulged in food purchase.

About 67% of the respondents declared as having food intolerance or digestive difficulties or simply aversions to certain foods in case of one or more family members. Intolerance, allergies, and/or aversions were for categories of milk derivatives, cereal derivatives, fishery products and meat. Many respondents stated as having more than one allergy/intolerance/aversion.

Regarding eating habits, 82% of the respondents declared to rarely consume *gnocchi*, while only 1% consumed *gnocchi* for several times a week (Figure 1A). These data confirmed that *gnocchi* were a niche product and, therefore, product innovation could help to reach further market segments. About 80% of the respondents preferred refrigerated *gnocchi* and only 3% declared a preference for frozen product (Figure 1B). According to these data, growth margins for the frozen product appeared to be high. Among the *gnocchi* choice parameters (Figure 1C), ingredients and visual appearance were fundamental or very important. Cost and brand were considered moderately important (47.2% and 41.4%, respectively). Calories generally never invoke concerns, as *gnocchi* are rarely eaten, although they have medium-to-low energy content.

A typical consumer of *gnocchi* is traditional eater, loyal to classic shapes, mainly the traditional and wavy ones (Figure 2).

The most popular packaging size was 250 g (45.7%) and 500 g (49.2%), probably because these were more

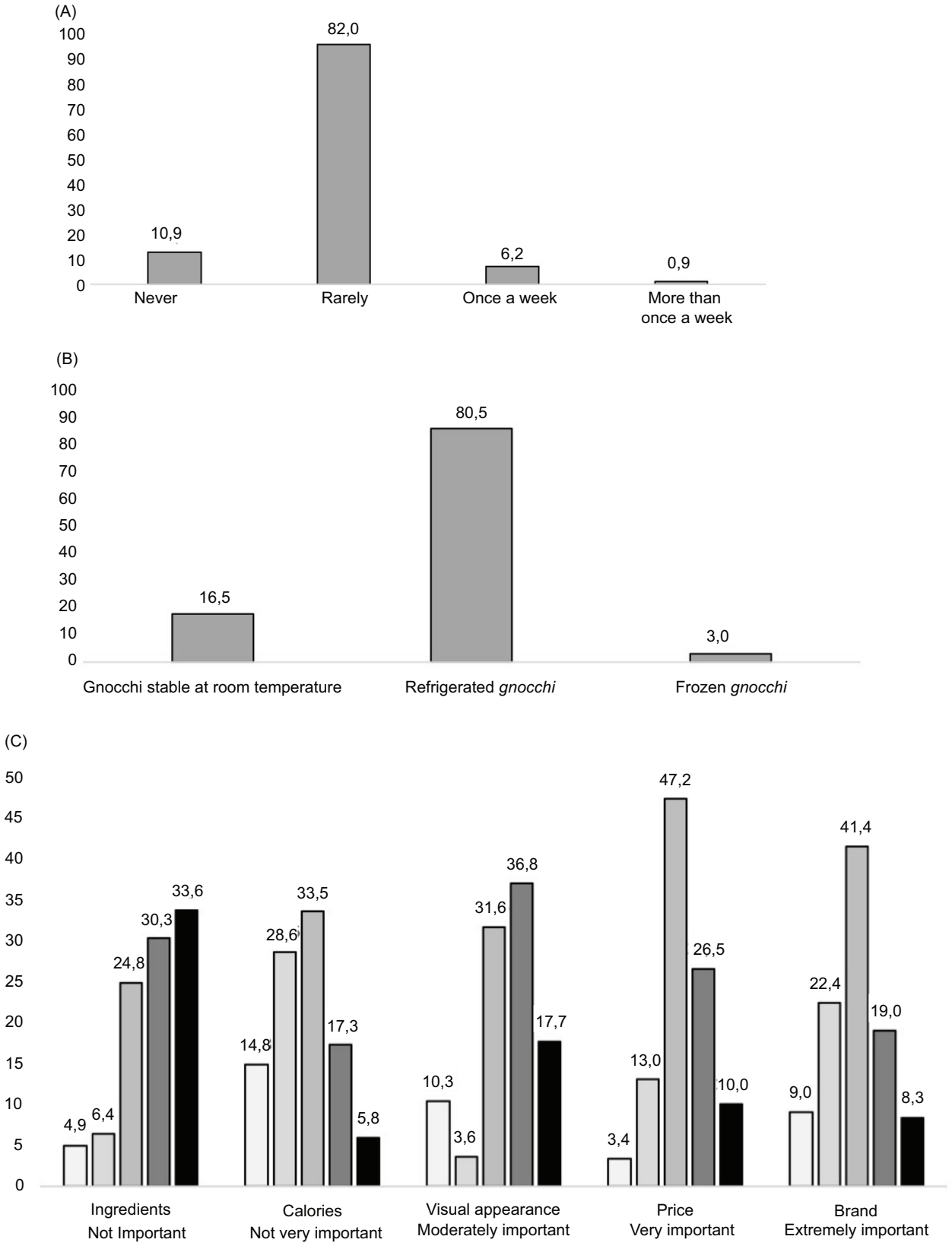

Figure 1. Online survey on *gnocchi*: (A) Frequency of consumption (%); (B) preference for preservation method (%); and (C) importance of some parameters of choice (%).

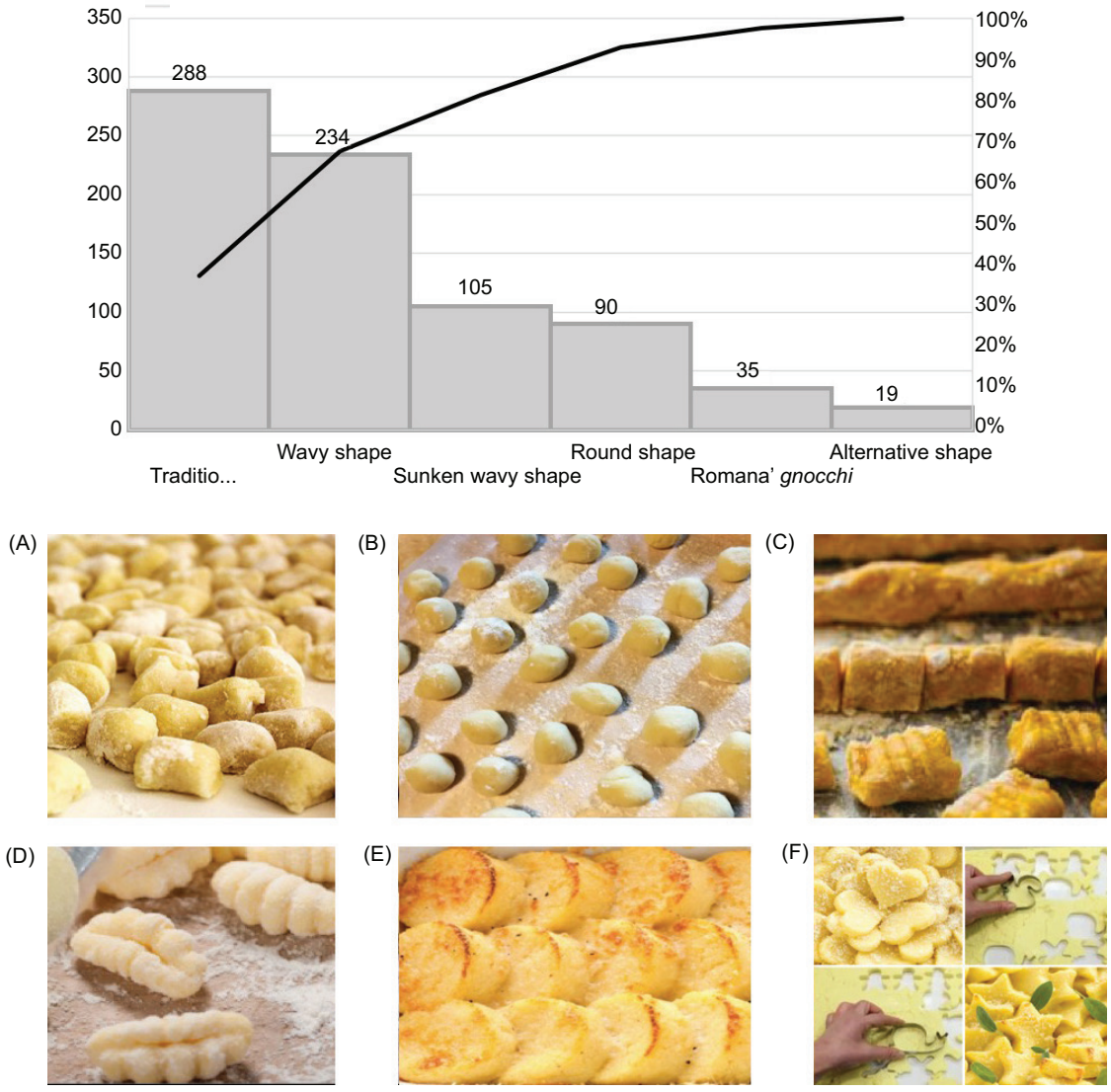

Figure 2. Online survey on *gnocchi*: preferences regarding shape: (A) classic shape; (B) round shape; (C) wavy shape; (D) sunken wavy shape; (E) 'Romana' shape; and (F) alternative shape.

suitable to the mentioned number of family members (Figure 3A). Bags were the most appreciated type of packaging, especially in a transparent version, perhaps because they occupied less space (Figure 3B). Trays were appreciated only if completely transparent, although their strength better protected from mechanical damages, especially compression forces. The packaging transparency correlated substantially with the importance of visual appearance in the choice of *gnocchi*.

The respondents considered traditional *gnocchi* as very pleasant (Figure 4A) and were less enthusiastic for the formulations containing other ingredients. *Gnocchi* with cauliflowers or stuffed with cheese were rated as unpleasant by increased proportion of respondents. These data evaluated consumers as traditionalists. The price per kilogram that respondents were willing to pay was <€2.50/kg and €2.50–4/kg, with a predominance who would be willing to pay <€2.50/kg for traditional *gnocchi* and *gnocchi* with cauliflower pieces, and €2.50/kg–4/kg for other types (Figure 4B).

Last but not least, the SURE model was estimated. The objective of the model was to identify significant variables affecting willingness to purchase and pay for different types of frozen *gnocchi*. As shown in Table 8, the SURE model outperformed well and presented a discrete number of statistically significant variables interpreting consumers' preference and behavior.

Selection of the variables shown in Table 8 is defined by a step-wise procedure, which led to a selection of 10

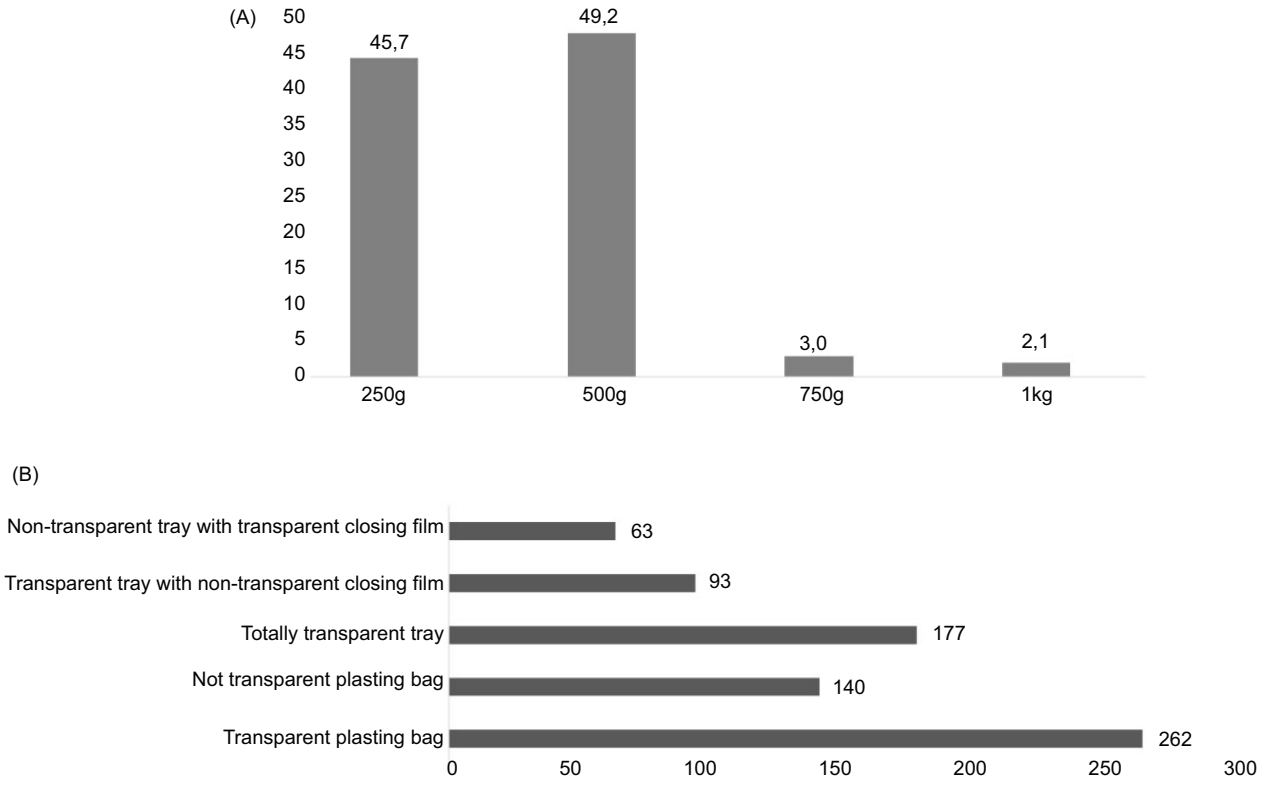

Figure 3. Online survey on *gnocchi*: preferences regarding (A) size (%); and (B) type of packaging (possibility to express more than one preference).

significant regressors. In detail, the results highlighted the following relations:

- *imp_price:* Represents the level of preference of consumers for low-price products. The mean coefficient, below –0.10, indicated the inverse relationship with the price that consumers are willing to pay, which confirms coherence with the economic theory of demand.
- *imp_ingr*: The importance of ingredients table in the label when choosing *gnocchi*. This variable shows a positive coefficient of about 0.1 average, indicating a direct relation with willingness to purchase and pay. Frozen *gnocchi* are preferred by people caring about ingredient information provided on the label.
- *gnocchi_amb:* This variable indicates the level of substitution between frozen *gnocchi* and those at room temperature (such as pasta). The negative value of the coefficient indicates the level of substitution between two products. In fact, the more the consumers prefer room-temperature *gnocchi*, the less they are willing to purchase frozen *gnocchi*.
- *gnocchi_hab:* It indicates consumer habits of eating *gnocchi*. This variable is measured in terms of frequency of consumption of *gnocchi* on a scale of 1–5. A negative value of coefficient indicates that consumers that are more frequent have weaker preferences for frozen *gnocchi*. Maybe, they prefer fresh ones.
- *Intolerant*: When a family member presents intolerance, such as gluten, *gnocchi* could be preferred to pasta. In fact, in these cases, consumers are willing to purchase and pay more.
- *Income*: A positive sign for this variable confirms that the higher the income, the higher the willingness to pay for frozen *gnocchi*. Following the economic theory, if income and consumption have positive relationship, then the good is perceived as of normal quality whereas if there is an inverse relationship, the good is perceived as of inferior quality. Therefore, frozen *gnocchi* are not perceived as low-quality products.
- *no_family:* Results of the analysis show that the number of family members in a household has a positive relationship with the price consumers are willing to pay for frozen *gnocchi*. Such result could be an interesting one, because bigger families could, indeed, prefer frozen *gnocchi*, compared to fresh ones, as they could be stored in fridge for a longer period.
- *Gender:* Results highlight another important variable for the identification of the target. Male consumers are

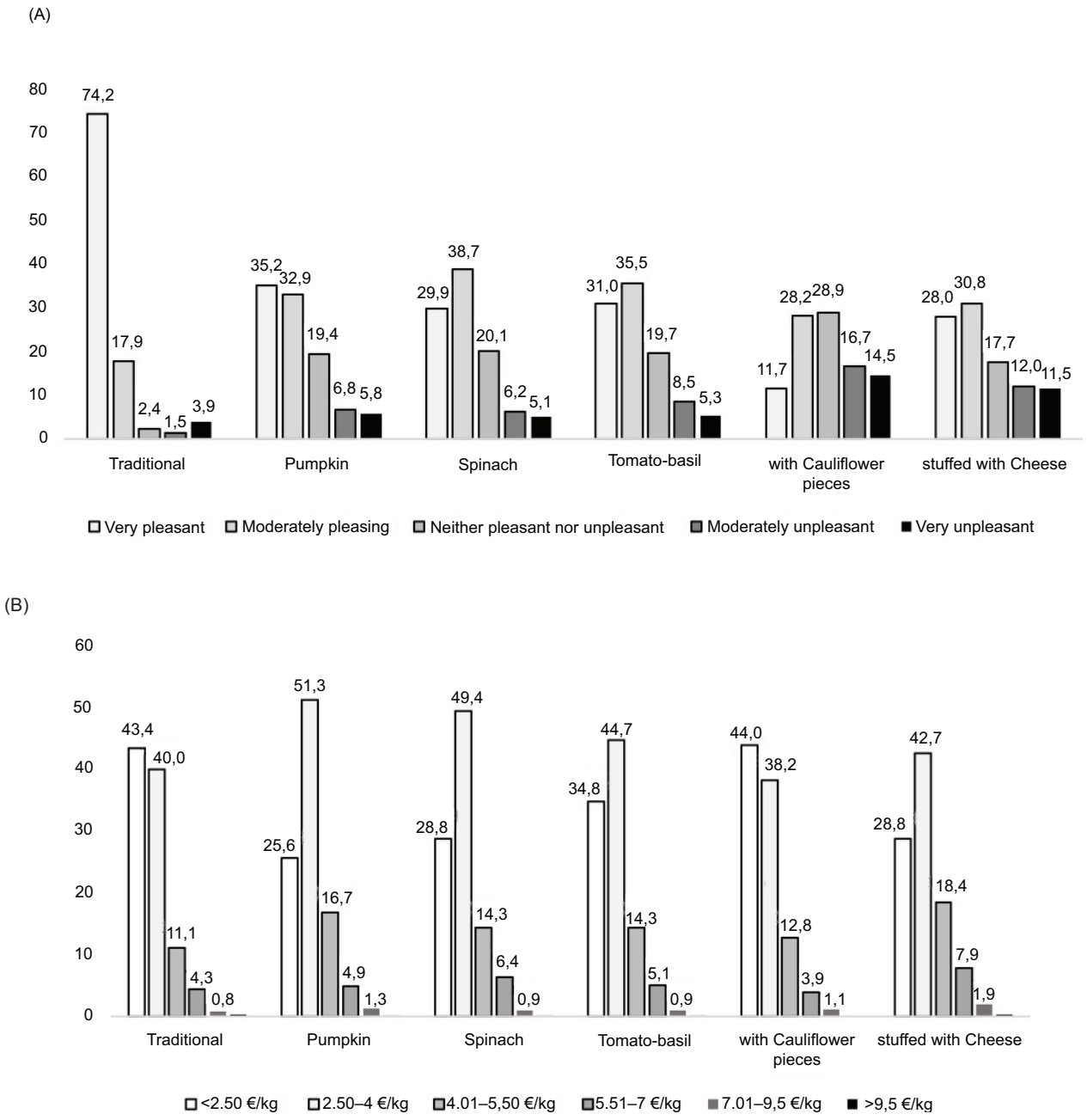

Figure 4. Online survey on *gnocchi* preferences: (A) regarding formulations; and (B) distribution (%) of respondents in relation to the price they are willing to pay for various formulations.

willing to pay more for frozen *gnocchi*, compared to female consumers.

- *Age:* Young consumers are less willing to pay and buy frozen *gnocchi*, compared to elderly ones.
- *dim_city*: It indicates the dimension of the town/city of consumers. Results of this estimation show that people living in bigger cities and metropolitan areas would prefer frozen *gnocchi*.

Minimal differences emerged on comparison of results among different types of *gnocchi*. The most important is about household with intolerant people. They would mostly purchase traditional *gnocchi* over other varieties with flavors and condiments (spinach, cheese, pumpkin, etc.). Such a result could be related not only to intolerance but to the presence of more allergies.

The following variables never significantly affect the respondents' willingness to pay:

- Geographical origin: There is no geographical influence, perhaps because *gnocchi* are known and

Table 8. Results of seemingly unrelated regression estimating preferences of frozen *gnocchi* consumers.

Variables	p_traditional	p_punp	p_spinach	p_tomato	p_cheese
imp_price	–0.139**	–0.145**	–0.103*	–0.128**	–0.158**
	[0.045]	[0.046]	[0.046]	[0.045]	[0.053]
imp_ingr	0.125**	0.123**	0.120**	0.125**	0.088+
	[0.039]	[0.040]	[0.040]	[0.039]	[0.046]
gnocchi_amb	–0.269+	–0.13	–0.058	–0.175	–0.23
	[0.139]	[0.143]	[0.144]	[0.141]	[0.164]
gnocchi_hab	–0.266*	–0.253*	–0.055	–0.151	–0.264*
	[0.114]	[0.117]	[0.118]	[0.115]	[0.134]
Intollerant	0.260*	0.12	0.04	0.051	0.049
	[0.110]	[0.113]	[0.114]	[0.111]	[0.130]
Income	0.220**	0.210**	0.210**	0.161**	0.266**
	[0.053]	[0.054]	[0.055]	[0.053]	[0.062]
no_family	0.090*	0.065	0.100*	0.088*	0.036
	[0.042]	[0.043]	[0.043]	[0.042]	[0.049]
Gender	–0.284**	–0.215*	–0.298**	–0.342**	–0.262*
	[0.107]	[0.109]	[0.111]	[0.108]	[0.126]
Age	0.084+	0.128**	0.047	0.098*	0.061
	[0.044]	[0.045]	[0.046]	[0.044]	[0.052]
dim_city	–0.061	–0.046	–0.074+	–0.037	–0.008
	[0.041]	[0.042]	[0.042]	[0.041]	[0.048]
Constant	2.984**	2.899**	2.673**	2.624**	3.279**
	[0.339]	[0.347]	[0.351]	[0.342]	[0.400]
Observations	532	532	532	532	532
R^2	0.131	0.118	0.089	0.1	0.092

The standard error values are shown in square brackets. Levels of significance of the variables: ** p<0.01; * p<0.05; +p<0.1. R^2: coefficients of determination

consumed in a homogeneous manner throughout the regions.

- Brand: Respondents pay more attention to intrinsic quality than to brand appeal.
- Visual aspect: Appearance of the product does not represent an important variable regarding the willingness to pay, as it affects in advance the decision to buy the product.
- Energy intake.
- Average expenditure for food purchases: *Gnocchi* are consumed infrequently; therefore, as they do not significantly affect expenditure, even consumers that spend less on food afford to buy them.
- Subject responsible for family purchases.
- Employment status.
- Level of education.

Conclusion

Based on microbiological criteria, it is possible to express a positive evaluation on the hygienic–sanitary suitability of frozen *gnocchi*, although, also considering their physico-chemical characteristics, strict compliance with cold chain and avoidance of thermal abuse are required. The nutritional characteristics make *gnocchi* an excellent first course, although cheese-stuffed *gnocchi* also guarantee a certain amount of protein. Sensory evaluation highlights the good quality of the product if evaluated at an optimal cooking period, after which deterioration of parameters, such as texture and stickiness, takes place. The stuffed-cheese *gnocchi* obtained the highest sensory scores.

Finally, concerning the new product's sale potential, the estimation of the model allowed identifying the ideal target: the frozen *gnocchi* presented as traditional or prepared with other ingredients. Frozen *gnocchi* are perceived as 'normal' good product and not a low-quality food. The market survey has clearly highlighted the profile of a traditionalist consumer regarding the formulation (preference for the 'base' preparation), shape (classic and wave) and packaging (transparent).

The consumer does not appear to spend a large amount, regardless of the product type. In any case, the price that respondents are willing to pay increases with the importance attributed to product's ingredients, in the presence of food intolerances/allergies/repulsions, with increase in income, number of family members and age. The willingness to pay decreases with the importance that respondents attribute to the price increases as well as increase in the frequency of consumption.

Males appear more likely to pay than females. The ideal consumer is a city male of middle age, with high income and a big family. According to the results obtained, innovation is possible, but it must be 'mild' and, while there is a realistic opportunity for the industry to produce and sell frozen *gnocchi* to a good target that would increase market interest, would always be in presence of a niche product.

Declaration of Competing Interest

The authors declared that they had no known competing financial interests or personal relationships that could have influenced the results reported in this paper.

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