The Annals of the University Dunarea de Jos of Galati
Fascicle VI – Food Technology (2019), 43(2), 157-172

ORIGINAL RESEARCH PAPER

SUSHI FROM COMMON CARP (*Cyprinus carpio*): PREPARATION METHOD, CONSUMER ACCEPTANCE AND ECONOMIC AND FINANCIAL VIABILITY

PIOTR KULAWIK*, JOANNA TKACZEWSKA**, MARZENA ZAJĄC**, ANDRZEJ SZYMKOWIAK***, WŁADYSŁAW MIGDAŁ**

**Department of Animal Product Technology, Faculty of Food Technology, University of Agriculture, ul. Balicka 122, 30-149 Krakow, Poland*

****Department of Animal Product Technology, Faculty of Food Technology, University of Agriculture, ul. Balicka 122, 30-149 Krakow, Poland,*

****Department of Commerce and Marketing, Institute of Marketing, Poznań University of Economics and Business, Poznań, Poland*

*Corresponding author: kulawik.piotr@gmail.com

Received on 17th September 2019
Revised on 19th November 2019

The paper evaluates and describes the possibility of using common carp (*Cyprinus carpio*) as an ingredient for sushi production. The carp fillets were subjected to various treatments resulting in creation of three types of marinated carp fillets, two types of carp tartare and one type of baked carp which were used as ingredients for six different maki sushi rolls. The consumer's acceptance tests were performed on 97 respondents, who evaluated the appearance, texture, odour, taste and overall quality of created sushi rolls using the 9-point hedonic scale. All sushi rolls were not only acceptable, but also desirable by the consumers, from which 86.6% reported the willingness to purchase such prepared sushi set in the future. The economic analysis showed that using carp instead of salmon or tuna may be profitable. The sushi rolls were also analyzed for heavy metal content (Hg, Cd, Ni, Pb, As). High levels of cadmium, nickel and arsenic were detected in all created sushi rolls. The study proves that common carp can be a desirable and economically viable option as a sushi ingredient.

Keywords: sushi, carp, consumer acceptance test, heavy metal residues, economic viability

Introduction

Fish are one of the most important sources of animal protein. At the end of the XX century the global supply of fish was mainly dependent on marine fisheries. However last two decades brought the decrease of marine fisheries due to overfishing. Currently fish production is gradually taken over by intensively developing aquaculture (Bostock *et al.*, 2010).

https://doi.org/10.35219/foodtechnology.2019.2.11

Since early years of the XXI century there has been a notable decrease in carp production despite the fact that the development of aquaculture is one of the key elements of European Union strategy for the fisheries development (European Parliament, 2013). One of the main obstacles in development of carp aquaculture is the problem with carp sales. The changes, that are the effect of the evolution of the current consumption model, result in lower demand for the carp sold in the current form, consisting mostly of the whole fish sale (European Commission, 2012). At the same time there is an increased interest among the consumers from Western and Central Europe in functional and convenient food products. The increase in carp sales can be achieved by extending the range of products offered to the consumers, which in turn requires the development of carp processing industry.

Sushi as a modern cuisine saw its most dramatic and intense development and transformation in the XX century. Between 1988 and 1998, the number of sushi restaurants in the USA quadrupled (Brown, 2012). In recent years, sushi has been available as a ready-to-eat product, and its form is designed by the sushi processor. Ready-to-eat sushi can be currently found in supermarkets, delicatessen and local shops (Hsin-I Feng, 2012). Although sushi survived almost 2000 years of changes, it seems that the biggest challenge is still ahead – the dramatic decrease in global fish supply. Almost all fish species which are traditionally used in sushi and sashimi, such as Atlantic bluefin tuna, are currently listed as species endangered with extinction in their natural habitat (Karakulak *et al.*, 2004), which increased their cost and reduced availability.

In order to inhibit the decreasing demand for carp, which is a necessary condition to increase the European carp aquaculture production, new carp products have to be designed. Such new products have to be attractive for the consumer who is searching for natural and healthy but also convenient and modern food product. On the other hand it should be economically viable for the processor, thus, the wastes should be minimized, and the production process should not involve high costs of investment (Cooper and Kleinschmidt, 1987). Carp sushi could be one of such new products although special care should be given during the design process, since sushi is a product in which fish bones are unacceptable, and the muscle structure of the fish should be intact in at least part of the prepared sushi products. Thus, the aim of this study was to design new carp sushi products, which would be acceptable by the consumers and economically viable for the potential processors. Since the literature regarding sushi processing, including the methodology of sushi preparation, is relatively scarce, the secondary aim of the study was to present the detailed methodology of sushi preparation, which could be used by other interested parties and could improve the development of sushi processing among the food technology sciences. Moreover, because consumers were asked to assess the threat related to sushi consumption and one of the main concerns associated with fish and seafood consumption is heavy metal residues (Marcotrigiano and Storelli, 2003), the tertiary aim of the study was to confirm the safety of produced sushi in terms of heavy metal residues.

Materials and methods

Ingredients preparation

Fresh skinless carp fillets were acquired from a local processor located near Cracow, Poland. The sushi ingredients: nori, rice, soy sauce, rice vinegar, wasabi powder, masago and sesame were acquired from sushi ingredients wholesale. The rest of ingredients were acquired from local vendors. Carp fillets were divided into 5 parts (A, B, C, D and E) using 4 cuts (Figure 1). Parts marked as B and C contained all bones of the carp fillet, part D contained the strip of belly fat and harder muscle tissue. The remaining parts labeled as A and E were the most valuable parts of the fillet. All fillet parts were then frozen and stored for 48 hours (parts A and E) and 96 hours (parts B, C and D) at -20ºC in order to eradicate the possible parasite infestation. Afterwards the fillets were thawed at 4ºC for 24 hours.

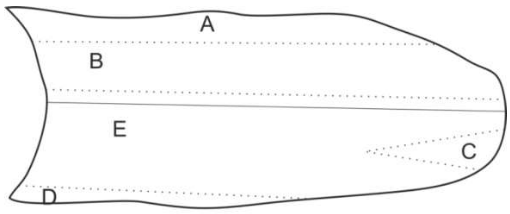

Figure 1. Cutting lines and fillet parts division: ..... – cutting line; A, E – parts of fillet without bones used for carp marinates; B, C, D – parts of fillets with bones, used for carp tartare and baked carp

Such prepared carp fillet parts were used to create six different products: three types of marinated carp: carp marinated in basil (CB), carp marinated in dill (CD) and carp marinated in parsley (CP), two carp tartare: carp tartare with leek (TL) and carp tartare with parsley (TP) and one baked carp (BC). The detailed recipes for each product are shown in Table 1.

Marinated carps (CB, CP and CD) were created from fillet parts labeled as A and E, by thoroughly covering the surface of the fish meat with chopped parsley, basil or dill and the rest of ingredients and wrapping tightly the whole product in food wrap. Such prepared products were then left for 48h at 4ºC and used as a sushi ingredient.

Carp tartare (TP and TL) was created from fillet parts labeled as B, C and D. Fillet parts were grinded in meat grinder (MEW 613, MADO, Germany) with 2 mm holes diameter in the end plate, mixed with chopped leak or parsley and rest of ingredients and used as a sushi ingredient.

Baked carp (BC) was prepared from fillet parts labeled as B, C and D. Carp fillet parts were mixed with soy sauce and chilli pepper and baked in convection oven for 20 minutes at 160ºC. Afterwards the fish was cooled to the temperature of approximately 20ºC, grinded on meat grinder with 2 mm holes diameter in the end plate and used as a sushi ingredient.

Table 1. Recipes for marinated carp, carp tartare and baked carp

Ingredient	%	Cost for 1 kg of final product [USD]
Carp marinated in parsley (CP)		
Carp fillet (Parts A and E)	83	7.03
Sodium chloride	7	0.01
Parsley leaves	5	0.66
Lemon juice	5	0.29
Total cost of 1kg of product		***7.99***
Carp marinated in basil (CB)		
Carp fillet (Parts A and E)	85	7.20
Sodium chloride	5	<0.01
Basil	4.5	0.89
Sucrose	4	0.03
Black pepper	1.5	0.21
Total cost of 1kg of product		***8.33***
Carp marinated in dill (CD)		
Carp fillet (Parts A and E)	83	7.03
Sodium chloride	6.5	0.01
Sucrose	6	0.04
Dill	3	0.52
Black pepper	1.5	0.21
Total cost of 1kg of product		***7.81***
Carp tartare with leek (TL)		
Carp fillet (Parts B, C and D)	72.5	6.14
Leek	14	0.12
Soy sauce	10	0.19
White sesame	3.5	0.10
Total cost of 1kg of product		***6.55***
Carp tartare with parsley (TP)		
Carp fillet (Parts B, C and D)	92	7.83
Parsley leaves	5.1	0.67
Lemon juice	2.5	0.14
Powdered ginger	0.4	0.02
Total cost of 1kg of product		***8.66***
Baked carp (BC)		
Carp fillet (Parts B, C and D)	84	7.11
Soy sauce	13	0.25
Chilli pepper	3	0.10
Total cost of 1kg of product		***7.46***

Dry sushi rice (*Oryza sativa* ssp. Japonica) was firstly washed four times in water basin, using a 5:1 v/v water to rice ratio. Afterwards the rice was cooked with water in electric rice cooker (Bartscher 150.525, Germany) using the 1:1 water to washed rice volume ratio (1L of water per 1L of washed rice). The cooking lasted for approximately 30-45 minutes, until there was no free water left. Afterwards the rice was mixed with vinegar mixture (containing 52% of rice vinegar, 42% of sucrose and 6% of NaCl) using 0.125:1 volume ratio of vinegar mixture to washed rice (125 mL of vinegar mixture per 1L of washed rice). The rice with vinegar mixture was then gently mixed, left to cool down to the temperature of approximately 40ºC and used as a sushi ingredient.

Wasabi paste was prepared using the wasabi powder, which contained: horseradish (*Armoracia rusticana*), mustard, glucose, tartrazine and brilliant blue FCF. The powder was mixed with water using wasabi to water weight ratio of 1:2 (1 kg of wasabi powder for 2 kg of water) and used as a sushi ingredient.

Sushi preparation

Six different types of maki-sushi rolls were manually produced, one for each carp product (Table 2). Rice together with the rest of ingredient was placed on nori sheet and formed using a bamboo mat into circular futomaki (nori on the outside) or uramaki (rice on the outside) roll. Exactly 4 g of produced wasabi paste was smeared over the entire length of roll before rolling. Each roll was then stored for 18 hours at 4ºC until further analysis. Three rolls from each maki-sushi was randomly selected, grinded and homogenized using MPW-120 laboratory homogenizer (MPW Med. Instruments, Warsaw, Poland).

Such prepared samples were used for the heavy metal residues analysis. The rest of maki-sushi rolls were used for consumer's acceptance test. Directly before the acceptance test, produced sushi rolls were cut into 10 uniform pieces and exactly 4 drops of soy sauce were placed on each piece.

Consumer's preference and acceptance tests

The consumer's acceptance test was performed in the sensory evaluation laboratories located at Food Technology Faculty of University of Agriculture in Cracow. Exactly 100 consumers participated in the analysis from which 3 respondents were excluded due to allergies on one of the ingredients of evaluated maki-sushi. Except for the food allergies no special selection of the respondents has been carried. From 97 consumers included in the study 85.6% were women and 14.4% were men. 34.0% of respondents were aged 19-21 years, 50.5% were 22-24 years old, 7.2% were 25-30 years old and 8.3% were above 30 years old. The average weekly expenditures on food products per person were less than 25 USD for 25.8% of respondents, 25-37.5 USD for 50.5% of respondents and above 37.5 USD for 23.7% of respondents. 79.3% of respondents were responsible for purchasing groceries in their household.

Before the acceptance assessment all consumers were registered and instructed not to smoke or eat any meals and drink only water for 2 hours before the planned evaluation. The evaluation consisted of two tests: consumer preference test and acceptance test. During the first test the consumers were asked to fill in the questionnaire which contained question regarding the fish and sushi consumption patterns. During the second test, after filling the questionnaire, each respondent was taken into individual cubical and given a white neutral plate with one maki-sushi pieces per product (the total of six maki-sushi pieces), together with a cup of water and asked to grade the appearance, odour, texture, taste and overall quality using the 1 (not acceptable) to 9 (perfect) hedonic scale. All presented maki sushi were labelled using three, randomly selected, digit code. Afterwards the consumers were asked if they would purchase a set presented during evaluation and for what price. During the whole test, respondents remained anonymous and were unaware of the fish species that was used in the production of sushi.

Table 2. Recipes for carp sushi rolls

Ingredient	Amount [g]	Cost for 1 roll [USD]
Uramaki roll with carp marinated in parsley		
Carp marinated in parsley	40	0.32
Boiled rice	215	0.14
Cucumber	15	0.01
Mayonnaise	10	0.03
Red pepper	10	0.03
Nori	3 (1 sheet)	0.09
Wasabi paste	4	0.01
Orange masago (topping)	15	0.09
Total	***312***	***0.72***
Uramaki roll with carp marinated in basil		
Carp marinated in basil	40	0.33
Boiled rice	215	0.14
Cream cheese	15	0.08
Cucumber	15	0.01
Red pepper	10	0.03
Nori	3 (1 sheet)	0.09
Wasabi paste	4	0.01
Sesame mix (topping)	15	0.07
Total	***317***	***0.76***
Futomaki roll with carp marinated in dill		
Carp marinated in dill	40	0.31
Boiled rice	230	0.15
Cream cheese	15	0.08
Cucumber	15	0.01
Nori	3 (1 sheet)	0.09
Wasabi paste	4	0.01
Total	***307***	***0.65***
Futomaki roll with carp tartare with leek		
Carp tartare with leek	50	0.32
Boiled rice	230	0.15
Nori	3 (1 sheet)	0.09
Wasabi paste	4	0.01
Total	***287***	***0.57***
Futomaki roll with carp tartare with parsley		
Carp tartare with parsley	50	0.43
Boiled rice	230	0.15
Nori	3 (1 sheet)	0.09
Wasabi paste	4	0.01
Total	***287***	***0.68***

Uramaki roll with baked carp		
Baked carp	60	0.45
Boiled rice	215	0.14
Cucumber	15	0.01
Mayonnaise	10	0.03
Nori	3 (1 sheet)	0.09
Wasabi paste	4	0.01
Sesame mix (topping)	15	0.07
Total	***322***	***0.80***

Heavy metal residues

The previously homogenized samples were dried in dryer at 103°C for 24 hours. For the analysis of cadmium, lead, arsenic and nickel 0.5 g of dried sample was mineralized with concentrated HNO_3 and 30% HCl (Suprapur, Merck KGaA, Darmstadt, Germany). Mineralization was performed in microwave oven (Anton Paar, Graz, Austria), in 1400 W (reaching time 10 minutes, holding for 20 minutes, cooling for 15 minutes). The further analyses were performed using the Inductively Coupled Plasma (ICP) on the Perkin-Elmer ICP-OES 7300 Dual View apparatus (Perkin-Elmer, Waltham, USA). The acquired results were calculated and presented as mg of element in kg of fish fillet.

The analysis of mercury content was performed on 30 mg of dried sample using AMA-254 Advanced Mercury Analyzer (Spectro-Lab, Łomianki, Poland) at 254 nm wavelength, according to the method described by Costley *et al.* (2000). Acquired results were calculated and presented as mg of mercury in kg of fish fillet. The detection limit for mercury content was 0.01 ng.

The analysis was performed in three repetitions, one from each maki-sushi roll. On each repetition, 3 analyses were performed on ICP apparatus.

Statistical analysis

The analysis of the impact of product attributes (taste, odor, texture, appearance) on its overall assessment was based on the accumulated empirical material ($p<0.05$). The model was tested by regressing, using ordinary least squares. A separate analysis for each different carp sushi roll was performed. Table 3 depict the multiple regression results. The analysis of the results for each type of sushi roll reached a reasonable level of significance: CB (R2=0.859; df =3, 91; F=185.098; $p<0.01$), TL (R2=0.839; df =43, 88; F=114.66; $p<0.01$), BC (R2=0.885; df =3, 90; F=231.733; $p<0.01$), CP (R2=0.878; df =4, 91; F=164; $p<0.01$), TP (R2=0.864; df =3, 88; F=185.891; $p<0.01$), CD (R2=0.803; df =3, 92; F=93.69; $p<0.01$).

Results and discussion

Analysis of consumer's questionnaires

The results from the first part of the questionnaire show that 42.7% of respondents consume sushi less frequently than once per year or do not consume sushi at all, 44.8% of respondents consume sushi few times per year and only 12.5% 1-2 times per month. This shows that although sushi is gaining popularity, the majority of the consumers still do not consume sushi on a regular basis. When asked, about factors that affect the frequency of sushi consumption, 82.5% of respondents wrote that the main obstacle in more frequent sushi consumption is its price, 23.7% of respondents also mentioned low availability of sushi restaurants and/or sushi in supermarkets and 6.2% of respondents would consume sushi more frequently if it was easier to prepare at home. Surprisingly only 2.1% of respondents answered that they would consume sushi more frequently if there were no raw fish or seafood in it. When taking into consideration that the average sushi meal in the restaurant costs approximately 15-25 USD, and that majority of the respondents spend weekly up to 37.5 USD on food products, the reason for such low sushi consumption among respondents becomes understandable. There is a big market demand for cheaper sushi product and since the majority of costs in sushi preparation comprises of the cost of fish and seafood (Table 2), the industry and restaurants should look for alternatives to replace expensive fish species such as salmon and tuna in order to reach a broader range of consumers. One of such alternatives could be carp, whose price is over two times lower than the price of salmon.

Table 3. Influence of individual factors on the overall quality score

	% of the overall quality score explained by sensory attributes	**% of influence on the overall quality score**			
		Odour	**Appearance**	**Texture**	**Taste**
Maki with CB	85.9	*ns*	15.8%	12.8%	80.2%
p		0.884	<0.001	0.007	<0.001
Maki with TL	83.9	20.0%	11.6%	17.9%	56.2%
p		0.005	0.043	0.007	<0.001
Maki with BC	88.5	*ns*	23.7%	28.9%	58.4%
p		0.064	<0.001	<0.001	<0.001
Maki with CP	87.8	15.3%	16.0%	20.5%	65.3%
p		0.002	<0.001	<0.001	<0.001
Maki with TP	86.4	28.2%	27.3%	*ns*	58.1%
p		<0.001	<0.001	0.066	<0.001
Maki with CD	80.3	22.0%	16.0%	25.5%	48.0%
p		<0.001	0.004	<0.001	<0.001

p - factor significance; ns – factor not significant ($p > 0.05$)

When asked about the expected shelf-life of a sushi product purchased in supermarket, 6.3% were expecting only 1 day, 18.9% expected 2 days and 22.1% expected 3 days of shelf life. Additional 44.2% respondents expected 4-7 days shelf-life, and only 8.5% of respondents required longer shelf-life. Both 3 and 7 day shelf-life can be currently achieved by the industry (Steffen *et al*., 2010), however prolonging the shelf-life could prove beneficial in order to distribute sushi to more remote areas.

Since one of the aims of the study was develop a product which could increase the carp consumption among the consumers it was important to establish the current frequency of carp consumption among the interviewees. The respondents marked the frequency of consumption of selected popular fish species consumed in Poland (salmon, tuna, trout, cod, mackerel, carp, pangasius catfish and other fish species) from few times in a week till never. Tuna was the most frequently consumed fish species followed by salmon and mackerel. The least consumed fish species were pangasius catfish and carp. 49.5% of respondents consumed carp less frequently than once per year or never, and additional 46.3% only few times per year. Considering that carp cultivation is the most important aquaculture sector in Poland, the trend of declining carp consumption, especially among younger generations, will result in serious economic implications if nothing changes.

Figure 2 shows respondents view on four statements regarding sushi quality. The statements were selected in order to receive information on how consumers perceive the quality of sushi sold in shops and supermarkets.

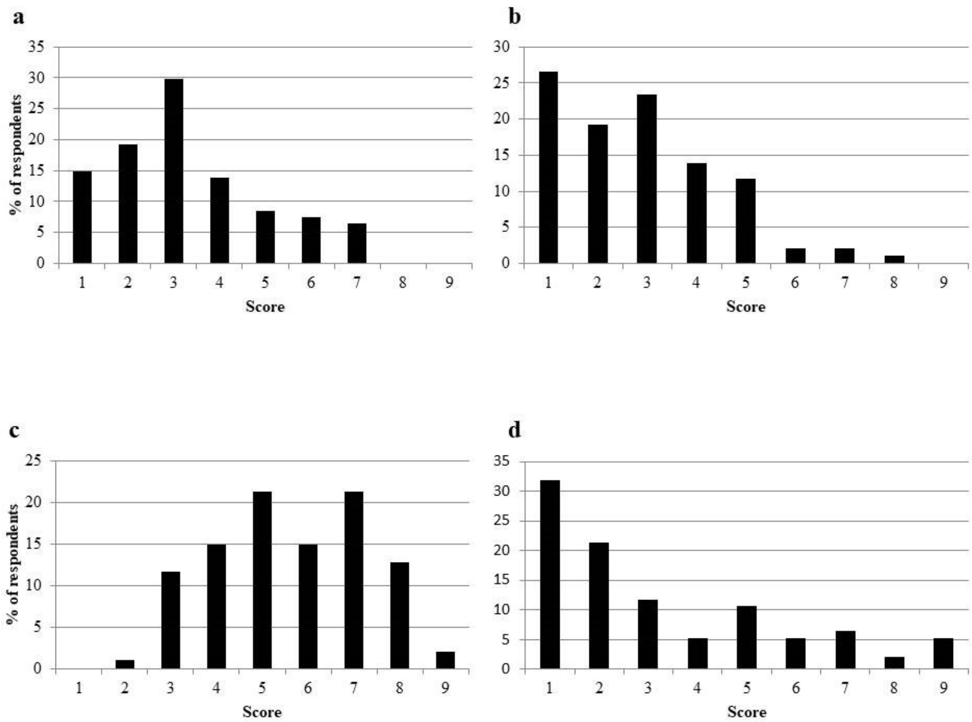

Figure 2. Respondents perception on some statements regarding sushi quality - results showed as % of respondents marking score from 1 (completely disagree) till 9 (completely agree) for each statement: (a) "Sushi acquired from supermarket is of equal quality as sushi purchased in restaurant", (b) "There is no taste difference between chilled and frozen sushi", (c) "Sushi purchased in shop/restaurant is completely safe to consume", (d) "Sushi would be much better if there were no raw fish/seafood in it"

The results show that most of the respondents view restaurant-made sushi as of higher quality (Figure 2a), did not accept freezing as an appropriate preservation method for sushi (Figure 2b), were not particularly concerned about safety of purchased sushi (Figure 2c) and do not think that sushi would be better if there were no raw fish/seafood inside (Figure 2d).

Those results indicate that sushi processors who plan to distribute their product through shops/supermarkets should pay extra attention to the appearance of the product and to ensure that proper quality and safety of the product is maintained throughout the whole shelf-life of the product. Since the refrigerated storage alone will not extend the shelf-life for more than approximately 36-60 h (Simpson *et al.*, 2008), freezing is unacceptable for most respondents, and heat treatment although acceptable cannot be used for all served sushi products, some additional preservation techniques should be used. One of such methods is to use marinated fish products instead of raw fish. Marinating can enhance the sensory quality of the product while extending its shelf-life (Lyhs *et al.*, 2001) and still can be considered as raw fish by consumers.

Consumer's acceptance test

As shown in Figure 3, all produced maki-sushi rolls received good scores from the respondents. The lowest scores for all parameters were given to maki rolls with carp tartare (both TP and TL). The average scores for overall quality ranged from 6.10 for maki roll with TP till 7.50 for maki roll with BC. This means that most of the consumers liked the product, despite the fact, that most of them do not normally consume carp. Although the maki rolls used for the analysis were carefully selected, so that they would all look similar, few consumers (11.3%) wrote in comments that the overall score was decreased by the appearance, which in their opinion was worse than in restaurants. This indicates that if prepared by using sushi-machines, the overall scores might be even higher.

The statistical analysis revealed that the factor which mostly influenced the overall quality of produced maki rolls was the taste, which accounted for 48-80% of the overall quality score. The scores for odour did not significantly influence the overall quality scores for maki rolls with CB and BC, although affected the scores for all other analyzed maki rolls. This is valuable information for sushi processors, since sushi sold in the retail chains is usually packed, thus, odour is not detectable.

About 86.6% of consumers declared that they would purchase the presented set of six maki-sushi pieces, if it was available in retail. From those 86.6%, 12.8% were willing to pay 2.5 USD, 53.5% were willing to pay 4–5 USD, 24.4% were willing to pay 6.5-7.5 USD and 8.1% were willing to pay 9-10 USD for the whole set. Only 1 respondent declared to pay bellow 2.5 USD. The statistical analysis showed no correlation between the amount the respondent's average weekly expenditure on food products and the price they would be willing to pay for the proposed sushi set.

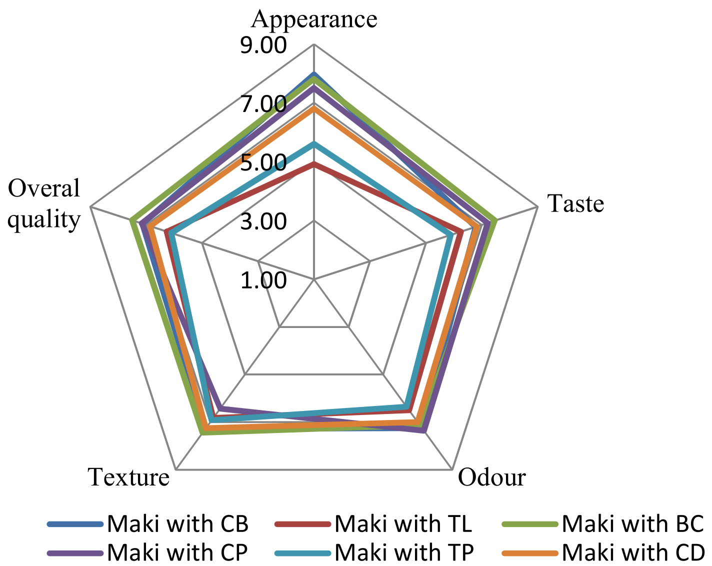

Figure 3. The results of consumer's acceptance test

Economical and financial viability

The following economic viability analysis was performed based on the Polish market. The type of costs is relatively constant, thus, after recalculating the changes in costs value the analysis can be used also on different European markets.

The gross price of a sushi set available in main retail chains ranges from 2.5-4.5 USD for a 7-12 pieces sushi set which is well within or even bellow the price range indicated by the respondents in this study. The most popular fish species used in those sushi packages is salmon. Since the production costs, such as manpower, utilities or packaging should be on the same level when using salmon and carp sushi, the main variable is the cost of fish species used in sushi production. Taking into consideration that the wholesale price of skinned carp is approximately half the price of a skinned salmon and the price of fish used in the production of each maki roll calculated in Tables 1 and 2, using carp instead of salmon will decrease the production costs by 0.3-0.4 USD for each roll. One maki roll is equal to 10 sushi pieces, which is a regular small sushi set. Potential producer of carp sushi can either increase his profit margin by 0.3-0.4 USD while maintaining the same price as for salmon sushi, or decrease the price by approximately 10% for the customer, while maintaining the same profit margin as salmon sushi producers.

The investment costs for starting a new sushi production line can be relatively low. Many sushi processors are currently producing sushi manually, which means that the required investment can be limited to the purchase of a steamer for rice production and a packaging machine. On the other hand in order to achieve higher production yields processors could invest in the purchase of sushi production machines. The cost of purchasing a new set of machines for maki sushi production, which constitutes of rice mixing machine, sushi roll machine and sushi rolls cutter is approximately 35 000 USD, based on price quotations received for Suzumo sushi machines (Suzumo, Osaka, Japan). Based on the capacity of such set (approx. 250 sushi sets/h) the solely reduction of costs by replacing salmon with carp (0.3 USD per set) can result in return of investment after approximately 60 days when using one 8h working shift or after 30 days when using two 8h working shifts.

The above analysis should be treated as an estimate, but it clearly shows, that carp sushi can be turned into a very profitable business. The investment costs and the return period of investment is relatively low, the profit margin can be much higher compared to salmon sushi and the product itself is well accepted by the consumers as shown in this study. In addition the proposed method of carp sushi production results in using the whole skinless carp fillet, without generating any wastes, similarly, to salmon. This means that 100% of fillet meat is used as a fully valuable raw material, which also influences the economic viability of the proposed product and also can have a positive impact on the environment.

Furthermore the development of carp sushi producers would create the constant all year long demand for carp meat, which in turn would be a step towards solving some of the problems faced by the carp aquaculture in Poland.

Heavy metal residues

Sushi is a mixture of boiled rice, vegetables, fish meat, seafood and various other components. It is difficult to establish the exact maximum level of heavy metal residues in such a complex product, since according to EU regulations the listed sushi components have different maximum acceptable levels (European Commission, 2006). Although it was expected, that the heavy metal residues in produced sushi rolls will be low, the acquired results show surprisingly high levels of cadmium, nickel and arsenic (Table 4), when taking into consideration the Tolerable Weekly Intake (TWI) for each heavy metal established by European Food Safety Authority (EFSA) (EFSA CONTAM Panel, 2009, 2011, 2015). Due to those findings we performed a follow-up analysis in order to establish the possible sources of the contamination. The follow-up analysis covered the levels of cadmium, arsenic, nickel and lead. The analysis of mercury was not performed, due to low level of this heavy metal in analyzed sushi rolls. The analysis was performed on nori sheets, wasabi powder and dry rice grains as the most probable sources of contamination. Other possible sources would include carp, vegetables and spices, however the perishable nature of those products caused that those ingredients were not available anymore when performing the follow-up analysis. The analysis revealed surprisingly high cadmium, nickel and arsenic level in nori sheets. Nevertheless produced sushi rolls contained only approximately 1% of nori, accounting for around 0.022 mg of cadmium which indicates that there were other sources of contamination. Carp could be one of such sources although our past studies performed on carp from the same aquaculture from which carp in this study was used, showed very low levels of this contaminant (Tkaczewska and Migdal, 2012). The TWI for cadmium is 2.5 µg/kg of body weight (EFSA CONTAM

Panel, 2011), which means that an adult weighing 70 kg, should not consume more than 0.175 mg of cadmium per week. Thus, consumption of 1 kg of sushi presented in this study could prove hazardous to the consumer, especially considering that sushi is not the only source of cadmium contamination in human diet (EFSA CONTAM Panel, 2012). High cadmium intake is associated with renal tubular damage, skeletal damage and osteoporosis and cancer including breast, bladder, endometrium and lung cancer (EFSA CONTAM Panel, 2012; Jarup *et al*., 1998).

Table 4. Heavy metal residues in produced carp sushi rolls and selected sushi ingredients (mg/kg of wet weight)

	Cd	Pb	Hg	As	Ni
Maki with TL	0.177 ± 0.001	0.202 ± 0.004	0.029 ± 0.001	1.157 ± 0.085	0.169 ± 0.017
Maki with PT	0.111 ± 0.006	0.124 ± 0.003	0.027 ± 0.000	0.967 ± 0.104	0.167 ± 0.007
Maki with CP	0.112 ± 0.011	0.137 ± 0.011	0.055 ± 0.000	0.817 ± 0.022	0.132 ± 0.012
Maki with CB	0.129 ± 0.017	0.269 ± 0.021	0.006 ± 0.000	0.725 ± 0.044	0.339 ± 0.028
Maki with CD	0.191 ± 0.005	0.110 ± 0.008	0.014 ± 0.000	1.016 ± 0.056	0.138 ± 0.017
Maki with BC	0.171 ± 0.010	0.277 ± 0.023	0.010 ± 0.001	0.686 ± 0.016	0.167 ± 0.009
Dry rice	0.040 ± 0.001	0.241 ± 0.004	-	0.141 ± 0.016	0.201 ± 0.003
Nori sheet	2.233 ± 0.453	0.407 ± 0.114	-	35.880 ± 7.753	0.705 ± 0.074
Wasabi powder	0.098 ± 0.005	0.369 ± 0.032	-	0.047 ± 0.006	0.809 ± 0.005

Total arsenic found in food products is divided into two forms: organic and inorganic and the latter is associated with higher toxicity (EFSA CONTAM Panel, 2009). The adverse effects of inorganic arsenic exposure include cancerogenesis, gastrointestinal injuries or coronary heart disease (Hojsak *et al.*, 2015; James *et al.*, 2015). The analysis in this study determined only the total arsenic thus, the potential toxicity is hard to establish (Almela *et al.*, 2006). Nevertheless the level of total arsenic is high enough to raise justified concern regarding consumer's safety. It is well established that various seaweeds contain high levels of arsenic although it is mostly present in the organic form of arsenosugar, which shows low cytotoxicity (Ebert *et al.*, 2016; Sakurai, 2002). Similarly, fish and seafood can also contain higher levels of arsenic (Pavlovičová and Šalgovičová, 2008) although mostly in organic form. On the other hand rice, which is a main ingredient of sushi is often associated with inorganic arsenic contamination (Hojsak *et al.*, 2015; Meharg *et al.*, 2008). Acquired results show that the main source of arsenic (approximately 0.36 mg/kg) in produced sushi rolls was nori. Other possible source of contamination could include fish or salt, since Pavlovičová and Šalgovičová (2008) found that salt can contain even up to 1.2 mg of arsenic/kg of salt.

Dietary exposure to nickel, can cause potential toxicity to kidneys and liver and also impair the reproductive system and fetus development. Although nickel is also considered a carcinogen, it is mostly related to nickel inhalation and not through oral administration. The established TWI for nickel is 2.8 µg/kg of body weight (EFSA CONTAM Panel, 2015), which means that the adult weighing 70 kg should not consume more than 0.196 mg of Ni weekly, thus, the produced sushi rolls could again prove hazardous for the consumer. High levels of nickel were found both in nori sheets and wasabi powder, however wasabi powder is further diluted with water in 1:2 ratio and then just small amount of produced wasabi paste is used, thus, neither nori nor wasabi powder explains such high nickel content in sushi rolls. High levels of nickel were also found in dry rice, however dry rice was thoroughly washed in water and then boiled, so its content in boiled rice used in maki rolls should be much lower.

The levels of mercury and lead were within the limits established by European Union (European Commission, 2006).

The heavy metal analysis was performed in order to confirm the safety of the produced products, meanwhile the acquired results were surprisingly alarming. Since all ingredients used in preparation of the presented sushi rolls were purchased from regular retail chains, we recommend performing a thorough investigation on the heavy metal residues in sushi available on the market, both in restaurants and retail chains, in order to evaluate if the results acquired in this study were incidental or is it a more widespread hazard for the final consumer.

Conclusions

The study showed that carp can be a possible alternative for a sushi ingredient, which will be not only acceptable but also desirable for the final consumer. Moreover, using carp as a sushi ingredient is economically viable and can prove much more profitable compared to traditional sushi fish species such as salmon or tuna. The proposed range of different sushi products shows that it is also possible to use 100% of skinless carp fillet, without generating any additional wastes, which is also important in terms of environmental and economic sustainability.

The heavy metal analysis showed surprisingly high levels of cadmium, arsenic and nickel, thus, it is recommended to investigate this matter further in order to assess the potential danger for the consumer's safety.

References

Almela, C., Jesús Clemente, M., Vélez, D. and Montoro, R. 2006. Total arsenic, inorganic arsenic, lead and cadmium contents in edible seaweed sold in Spain. *Food and Chemical Toxicology,* **44**(11), 1901-1908.

Bostock, J., McAndrew, B., Richards, R., Jauncey, K., Telfer, T., Lorenzen, K. Little, D., Ross, L., Nandisyde, N., Gatward, I. and Corner, R. 2010. Aquaculture: global status and trends. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences,* **365,** 2897-2912.

Brown, J. C. 2012. Entering the Era of Convenience Sushi: Changes in the Cultural Meaning of a Connoisseur Cuisine. *Intersect: The Stanford Journal of Science, Technology, and Society* **5**, 1-13.

Cooper, R. G. and Kleinschmidt, E. J. 1987. What makes a new product a winner: Success factors at the project level. *R&D Management,* **17**(3), 175-189.

Costley, C. T., Mossop, K. F., Dean, J. R., Garden, L. M., Marshall, J. and Carroll, J. 2000. Determination of mercury in environmental and biological samples using pyrolysis atomic absorption spectrometry with gold amalgamation. *Analytica Chimica Acta,* **405**, 179-183.

Ebert, F., Meyer, S., Leffers, L., Raber, G., Francesconi, K. A. and Schwerdtle, T. 2016. Toxicological characterisation of a thio-arsenosugar-glycerol in human cells. *Journal of Trace Elements in Medicine and Biology* **38**, 150-156.

EFSA CONTAM Panel. 2009. Scientific Opinion on Arsenic in Food 1. *EFSA Journal, 7***,** 1351.

EFSA CONTAM Panel. 2011. Statement on tolerable weekly intake for cadmium. *EFSA Journal, 9*(2).

EFSA CONTAM Panel. 2012. Cadmium dietary exposure in the European population. *EFSA Journal,* **10**(1), 2551.

EFSA CONTAM Panel. 2015. Scientific Opinion on the risks to public health related to the presence of nickel in food and drinking water. *EFSA Journal,* **13**(2), 4002.

European Commission. 2006. *Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs*.

European Commission. 2012. Carp *Cyprinus carpio.* Fact sheet. *Fisheries and aquaculture in Europe, 56*.

Regulation (EU) No 1380/2013 of the European Parliment and the Council of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC, 1380/2013 C.F.R. (2013).

Hojsak, I., Braegger, C., Bronsky, J., Campoy, C., Colomb, V., Decsi, T., Domellof, M., Fewtrell, M., Natasa, F., Mihatsch, W., Molgaard, C. and van Goudoever, J. 2015. Arsenic in Rice: A Cause for Concern. *Journal of Pediatric Gastroenterology and Nutrition,* **60**(1), 142-145.

Hsin-I Feng, C. 2012. The Tale of Sushi: History and Regulations. *Comprehensive Reviews in Food Science and Food Safety,* **11**(2), 205-220.

James, K. A., Byers, T., Hokanson, J. E., Meliker, J. R., Zerbe, G. O. and Marshall, J. A. 2015. Association between lifetime exposure to inorganic arsenic in drinking water and coronary heart disease in Colorado residents. *Environmental Health Perspectives,* **123**(2), 128.

Jarup, L., Berglund, M., Elinder, C. G., Nordberg, G. and Vanter, M. 1998. Health effects of cadmium exposure - a review of the literature and a risk estimate. *Scandinavian Journal of Work, Environment & Health,* **24,** 1-51.

Karakulak, S., Oray, I., Corriero, A., Deflorio, M., Santamaria, N., Desantis, S., and De Metrio, G. 2004. Evidence of a spawning area for the bluefin tuna (*Thunnus thynnus L.*) in the eastern Mediterranean. *Journal of Applied Ichthyology,* **20**(4), 318-320.

Lyhs, U., Lahtinen, J., Fredriksson-Ahomaa, M., Hyytiä-Trees, E., Elfing, K., and Korkeala, H. 2001. Microbiological quality and shelf-life of vacuum-packaged 'gravad' rainbow trout stored at 3 and 8 °C. *International Journal of Food Microbiology,* **70**(3), 221-230.

Marcotrigiano, G. O. and Storelli, M. M. 2003. Heavy Metal, Polychlorinated Biphenyl and Organochlorine Pesticide Residues in Marine Organisms: Risk Evaluation for Consumers. *Veterinary Research Communications,* **27**(1), 183-195.

Meharg, A. A., Sun, G., Williams, P. N., Adomako, E., Deacon, C., Zhu, Y.-G., Feldmann, J. and Raab, A. 2008. Inorganic arsenic levels in baby rice are of concern. *Environmental Pollution,* **152**(3), 746-749.

Pavlovičová, D. and Šalgovičová, D. 2008. Dietary intake of arsenic in the Slovak Republic. *Journal of Food & Nutrition Research,* **47**(1), 6-17.

Sakurai, T. 2002. Review: Biological effects of organic arsenic compounds in seafood. *Applied Organometallic Chemistry,* **16**(8), 401-405. doi:10.1002/aoc.325

Simpson, R., Carevic, E., Pinto, M. and Cortes, C. 2008. Development of frozen sushi: optimization and shelf life simulation. *Journal of Food Processing and Preservation,* **32**(4), 681-696.

Steffen, H., Duerst, M. and Rice, R. G. 2010. User Experiences with Ozone, Electrolytic Water (Active Water) and UV-C Light (Ventafresh Technology) in Production Processes and for Hygiene Maintenance in a Swiss Sushi Factory. *Ozone: Science & Engineering,* **32**(1), 71-78.

Tkaczewska, J. and Migdal, W. 2012. Porównanie wydajności rzeźnej, zawartości podstawowych składników odżywczych oraz poziomu metali ciężkich w mięśniach pstrąga tęczowego (*Oncorhynchus mykiss*) pochodzącego z różnych rejonów Polski. *Żywność Nauka Technologia Jakość,* **19**(5).