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Ratio of omega-6/omega-3 Fatty Acids of Spelt and Flaxseed Pasta and Consumer Acceptability

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Abstract

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The chemical composition and content of fatty acids in flaxseed and spelt flour were evaluated. The ratio of ω-6/ω-3 essential fatty acids is also analysed in spelt pasta and pasta with 0, 10, and 20% of flaxseed flour. Flaxseed flour has a better fatty acid profile than spelt flour, with low levels of saturated fat (approximately 8.99 g/100 g of flour) and a high concentration of linolenic acid (57.20 g/100 g of flour) and lower content of linoleic acid (15.98 g/100 g of flour), as well as superior ω-6/ω-3 ratio of 1 : 4. Flaxseed flour in pasta positively contributes to the daily intake of essential fatty acids recommended by nutritionists and the improvement of ω-6/ω-3 ratio. Although a new product is worse in texture quality, it will be acceptable to consumers who want to change their habits related to diet and enrich it with functional components.

Keywords: flour; pasta; fatty acids; ω-3/ω-6 ratio; sensory evaluation

Flaxseed (*Linum usitatissimum* L.) has been used in human nutrition for centuries because of its nutritional and health values. Flaxseed flour is used in the production of bakery and pasta products that have properties of functional foods. However, it should be taken into account that food products retain the technological and sensory quality despite the added flaxseed flour (Bojat *et al*. 2000; Payne 2000; Drusch & Mannino 2009; Villeneuve *et al*. 2013). Flaxseed contains important substances in its composition such as vitamins A, B, and E, magnesium, calcium, zinc, selenium, phosphorus, and it is also an excellent source of fibre and one of the best sources of ω-3 fatty acids and lignan (phytoestrogens with antioxidant effects). Furthermore, due to its composition, flaxseed has special health benefits for the female population such as reduction in the risk of occurrence of breast cancer (Lowcock *et al*. 2013) and menopausal symptoms (Thompson 2003), various cardiovascular and gastrointestinal diseases, diabetes, and osteoporosis (Rubilar *et al*. 2010; Villeneuve *et al*. 2013). Omega-3 is an essential fatty acid that must be present in the food and ingested as the body cannot synthesise it. These fats are vital for the human body especially for normal growth, development, and normal functioning of the organism in general. Moreover, they play an important role in the prevention of cardiovascular diseases and lowering blood pressure. There is now a lot of data emphasising the health benefits of consuming ω-3 fats that some countries have established recommended intakes expressed as the ratio of ω-6/ω-3 fatty acids (e.g. Canada 4 : 1–10 : 1) (Iafelice *et al*. 2008). Such actions resulted in high consumer interest in food that contains ω-3 fatty acids (Hernandez & Hosokawa 2011). In comparison

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with wheat (*Triticum vulgare*) grain, spelt (*Triticum spelta*) has better physical and mechanical properties. Spelt has a thicker layer/coat and fused chaff which protects it from insects, pesticides, field moulds, and their metabolites, it is more resistant against pathogenic microorganisms, i.e. diseases. Spelt is recognised for good nutritional composition, higher content of proteins, lipids, vitamins, and minerals compared to wheat grain (Abdel-Aal *et al*. 1995; Ruibal-Mendieta *et al*. 2005).

Pasta is suitable for improvement of eating plan because it is quick and easy to prepare, it is an easily digestible food as well as a good source of carbohydrates, and it is one of the most widely consumed foods in the world (Filipović *et al*. 2000, 2015). Therefore, pasta is selected as a model of the new functional product.

The aim of this paper is to analyse the chemical composition and content of fatty acids in flaxseed and spelt flour, and to determine the contribution of flaxseed to the ratio of fatty acids (ω-6/ω-3) in spelt pasta with the addition of flaxseed in the amounts of 10 and 20%. Additionally, paper presents the results of sensory analysis performed by trained evaluators and consumer acceptability of spelt pasta with flaxseed in regard to sensory properties.

MATERIAL AND METHODS

Experimental work: Phase 1

In the experimental work for making pasta the following ingredients were used: spelt flour, grown in Bačko Gradište in Serbia in 2013, purchased in a food store; flaxseed Imperial variety (with high linolenic content) from organic production, purchased in an organic food store in Novi Sad.

Basic chemical analyses. Basic chemical analyses (protein, starch, cellulose, reducing sugars, and lipid) of flaxseed and wholemeal spelt flour were determined according to the official methods of AOAC 15th edition, No. 930.25.

Pasta was made using the La Parmigiana D45 MAC 60 device with a moisture content of 31.5% during the test, length of crumbs production was 15 min (Kaluđerski & Filipović 1998). Flaxseed flour was added in amounts of 0, 10, and 20% to replace the spelt flour.

The content of fatty acids was analysed using a gas chromatography-mass spectrometry instrument (Agilent Technologies, Palo Alto, USA). Samples were prepared as described by Vujić *et al*. (2012); trimethylsulfonium hydroxide (TMSH), 0.2 M in methanol, was used as a derivatisation reagent; temperature programs were: 50–130°C at 30°C/min and 130–300°C at 10°C/min; injector temperature was 250°C; the flow of the carrier gas (helium) was 0.8 ml/min, split ratio of 1 : 50 was used for the injection of 1 µl of dissolved sample.

Quality of cooked pasta. Quality of pasta was evaluated in terms of cooking characteristics (volume increase and cooking loss). The method was described by Kaluđerski and Filipović (1998).

Sensory quality: Phase 2

Sensory analysis was conducted according to SRPS ISO 4121:2002 (Sensory analysis – Methodology – Evaluation of food products by methods using scales, by a panel of six trained evaluators). Evaluators identified descriptors, and scored sensory characteristics using 6-point scale (0 – unacceptable; 1 – bad; 2 – acceptable; 3 – good; 4 – very good; 5 – excellent quality parameter).

Additionally, stickiness of cooked pasta was also evaluated by the panel of six trained evaluators using numeric scores 0–10. High scores were allocated to pasta with smooth/unsticky surface (0 – unacceptable; 1 – extremely sticky; 2 – very much sticky; 3 – moderately sticky; 4 – slightly sticky; 5 – neither sticky nor smooth; 6 – slightly smooth; 7 – moderately smooth; 8 – very much smooth; 9 – extremely smooth; 10 – not sticky at all).

Descriptive statistical analyses for all obtained results were expressed as the mean ± standard deviation (SD), using StatSoft Statistica Version 10 (2010). Analysis of variance (ANOVA) was used to show relations between applied assays, while post-hoc Tukey's HSD test was evaluated for comparison of flour chemical composition, composition of fatty acids in flour and different formulations of pasta.

Consumer acceptability: Phase 3

The study of consumer acceptability was performed by 137 inexperienced tasters. The consumers were asked to evaluate the following sensory properties of pasta with 0, 10, and 20% of flaxseed: appearance, colour, flavour, texture, and overall acceptability using a 9-point Hedonic scale (1 – dislike extremely; 2 – dislike very much; 3 – dislike moderately; 4 – dislike slightly; 5 – neither like nor dislike; 6 – like slightly; 7 – like moderately; 8 – like very much; 9 – like extremely). The cooked pasta was served plain; the cooking method was described by Kaluđerski and Filipović (1998). The obtained scores were analysed using ANOVA, processed in SPSS Version 20 (2011) .

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RESULTS AND DISCUSSION

Experimental work. The chemical composition of flaxseed and spelt flour depends on plant variety, climate regions, and growing conditions. In this experiment, the flaxseed variety 'Imperial' with high percent of linolenic acid is used (Table 2). Table 1 shows that flaxseed flour has a statistically significantly higher content of crude protein than spelt flour, which is consistent with other studies (Pyler & Gorton 2008). The content of starch in spelt flour is slightly lower compared to wholemeal wheat flour (Pyler & Gorton 2008); while the content of starch in flaxseed flour is statistically significantly lower than in spelt flour, which is on the other hand a characteristic of oilseeds (Dimić 2005). The content of lipids in flaxseed flour is statistically significantly higher compared to wholemeal spelt flour. Spelt flour lipids consist mainly of triglycerides, phospholipids, lipoproteins, and glycolipids (Ruibal-Mendieta *et al*. 2005). Apart from a high lipid content, flaxseed flour also contains triglycerides and it is the main source of ω-fatty acids, i.e. α-linolenic acid (ALA), which accounts for 52% of the total fatty acids (Rubilar *et al*. 2010). Additionally, flaxseed flour is rich in cellulose, while the smallest difference between spelt and flaxseed is in total sugar content.

Flaxseed flour contains 47.2% less saturated fatty acids and its palmitic acid content is statistically significantly lower in comparison with spelt flour. Additionally, flaxseed flour has better nutritional composition of unsaturated fatty acids, it contains a statistically significantly higher level of linolenic acid (57.2 g/100 g of flour) and it has a statistically significantly lower level of linoleic acid (15.98 g/100 g of flour) in respect of spelt flour (Table 2). This proportion of essential fatty acids in flaxseed improves the ω-6/ω-3 ratio (e.g. in flaxseed flour this ratio is 1 : 4 and in spelt flour it is 20 : 1) (Table 2). Modern and dynamic society and inadequate diet caused an imbalance in the ω-6/ω-3 ratio (from 30 : 1 to 10 : 1) in favour of the ω-6 acid (McManus *et al*. 2011). According to the recommendations of nutritionists (www.eufic.org), this ratio should range from 1 : 1 to 2 : 1. Therefore, it is necessary to improve the intake balance of ω-3 compared to ω-6 fatty acids. The recommended ratio can be achieved by adding flaxseed flour into the pasta because it is rich in ω-3 fatty acids (Table 3).

Table 1. Chemical composition of flaxseed and spelt flour

Chemical composition (% DM)	Flour	
	flaxseed	spelt
Protein content	23.08 ± 0.21[a]	14.6 ± 0.18[b]
Starch content	5.71 ± 0.34[a]	61.48 ± 0.72[b]
Cellulose content	11.48 ± 0.13[a]	2.38 ± 0.09[b]
Reducing sugars content	1.25 ± 0.08[a]	1.68 ± 0.10[b]
Lipid content	47.56 ± 0.47[a]	3.54 ± 0.21[b]

DM – dry matter; results are presented as mean ± SD; different letter within the same row indicate significant differences ($P < 0.05$) according to Tukey's test; number of repetitions: $n = 3$

Table 2. Composition of fatty acids in flaxseed flour and spelt flour

Composition (g/100 g of flour)	Flour	
	flaxseed	spelt
Saturated fatty acid	8,99 ± 0.25[a]	19.03 ± 0.40[b]
Palmitic acid C16:0	5.03 ± 0.21[a]	18.21 ± 0.38[b]
Stearic acid C18:0	4.11 ± 0.09[a]	1.09 ± 0.02[b]
Monounsaturated fatty acid	18.09 ± 0.31[a]	15.95 ± 0.21[b]
Oleic acid C1:18	16.12 ± 0.29[a]	15.20 ± 0.19[b]
Polyunsaturated fatty acid	72.89 ± 0.47[a]	64.79 ± 0.39[b]
Linoleic acid C18:2n-6 (ω-6)	15.98 ± 0.28[a]	60.09 ± 0.32[b]
Linolenic acid C18:3n-3 (ω-3)	57.20 ± 0.41[a]	3.08 ± 0.05[b]
Ratio ω-6/ω-3	1 : 3.6	20 : 1

Results are presented as mean ± SD; different letter within the same row indicate significant differences ($P < 0.05$) according to Tukey's test; number of repetitions: $n = 3$

The chromatogram (Figure 1) clearly shows a difference in the content of fatty acids between spelt pasta and spelt pasta with addition of flaxseed flour in the amounts of 10 and 20% (400 000, 1 400 000, and 7 500 000 units, respectively).

The spelt pasta contains 0.16 g (per 100 g of pasta) of total fatty acids with the shares of ω-6 linoleic acid (0.096 g/100 g of pasta) and ω-3 linolenic acid (0.0048g/100 g of pasta) (Table 3). In the wholemeal spelt pasta ω-6 fatty acids make a share of 60% while ω-3 fatty acids make a share of only 3%, which is consistent with the literature (Abdel-Aal *et al*. 1995; Filipović *et al*. 2015), and the essential fatty acid ratio of ω-6/ω-3 is 20 : 1. The addition of flaxseed flour into spelt pasta in the quantities of 10 and 20% statistically significantly increases the share of ω-3 fatty acids, which results in the improved ratio of ω-6/ω-3, which is 6.7 : 1 and 1 : 1.2, respectively (Table 3). The International Society for the Study of Fatty Acids and Lipids (ISSFAL 2004) recommends

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Table 3. Fatty acids in spelt pasta with different shares of flaxseed flour

Fatty acids (g)	Spelt pasta with flaxseed (%)		
	0	10	20
Fatty acids	0.16 ± 0.05[a]	1.2 ± 0.14[b]	9.5 ± 0.21[c]
Linoleic acid C18:2n-6 (ω-6)	0.096 ± 0.010[a]	0.67 ± 0.09[b]	4.9 ± 0.20[c]
Linolenic acis C18:3n-3 (ω-3)	0.0048 ± 0.001[a]	0.10 ± 0.03[b]	5.9 ± 0.13[c]
Ratio ω-6/ω-3	20 : 1	6.7 : 1	1 : 1.2

Results are presented as mean ± SD; different letter within the same row indicate significant differences ($P < 0.05$) according to Tukey's test; number of repetitions: $n = 3$

dietary intake of 6.5 g/day of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Moreover, 100 g of pasta with 20% of flaxseed flour, as a daily food intake, provides a human organism with 5.9 g of ω-3 fatty acids that are necessary for the normal functioning. This is in accordance with the nutritionists' recommendations while the 1 : 1.2 ratio of ω-6/ω-3 represents an ideal ratio of essential fatty acids (McManus *et al*. 2011).

Quality of the cooked pasta is presented in Table 4. Volume increase is the ability of starch to swell and this parameter indicates that there were statistically significant differences between pastas with flaxseed (0 and 10%) and pasta with 20% of flaxseed. Cooking loss is a parameter of the cooked pasta quality and increases with addition of flaxseed. This parameter is satisfactory, because it does not make an impression of a creamy product when chewing, which is a very important sensory property for consumers. Moreover, Sissons *et al*. (2012) stated that for high quality pastas, this loss should not exceed 7–8% of the dry matter. The fact that neither pasta (with 10 and 20% of flaxseed) exceeds the 8% limit classifies them as high quality pastas in regard to cooking loss values.

Sensory analysis by trained evaluators. Figure 2 presents the results of a descriptive sensory analysis of pasta with different quantities of flaxseed flour. As expected, the addition of flaxseed flour strongly affected evaluated sensory properties, which is in accordance with other studies (Alpaslan & Hayta 2006; Aliani *et al*. 2012; Hernandez Barros Fuchs 2013). The same figure further shows that flaxseed decreases appearance and flavour scores (the highest descriptor 5 – excellent was in pasta with 0% of flaxseed and the lowest descriptor 3 – good was in pasta with 20% of flaxseed). Pasta with 10 and 20% of flaxseed flour has actually a flavour 'like flaxseed', which is different from pasta with 0% of flaxseed flour. Furthermore, the results suggest that the addition of flaxseed (10 and 20%) affects the descriptor value of colour (3 – good), making it more intensive. Descrip-

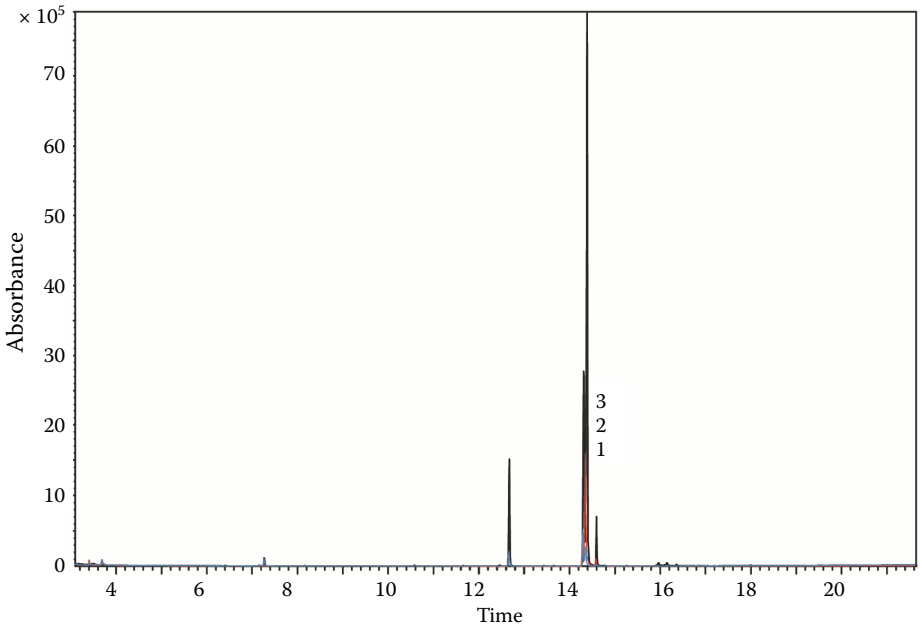

Figure 1. Chromatogram of liposoluble pasta extract with (1) 0, (2) 10, and (3) 20% of flaxseed flour

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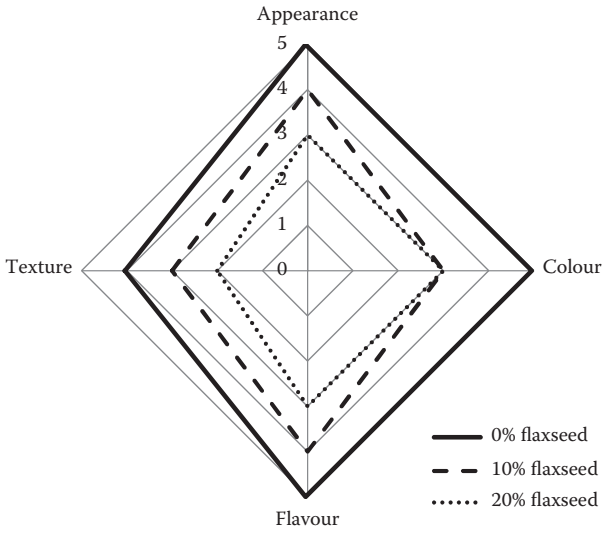

Figure 2. Sensory analysis of pasta with different quantity of flaxseed

tor values for texture decreased with the addition of 10 and 20% of flaxseed (to descriptor value 3 – good and descriptor value 2 – acceptable quality), which indicates that flaxseed had a strong influence on pasta texture. However, texture quality still remains in an acceptable range. Pasta with flaxseed flour has worse texture (fracturability) and appearance (smoothness) parameters but it has improved functional properties compared to pasta with 0% of flaxseed flour. These products are mainly designed for consumers interested in functional foods and those who are willing to improve the ω-6/ω-3 ratio in their diet.

The results of stickiness evaluation are also presented in Table 4. It can be concluded that statistically different stickiness was experienced for each pasta with flaxseed (10% – very much smooth and 20% – moderately smooth) and pasta with 0% of flaxseed (extremely smooth), which indicated that the quantity of flaxseed significantly influenced stickiness. Although the results presented in Table 4 indicated that pasta with the addition of 20% of flaxseed had lower quality of the final product compared to pasta with 0% of flaxseed, this product still retained the quality properties which should be acceptable for consumers.

Consumer acceptability. The results of pasta evaluation by consumers (Table 5) are in line with the results of trained evaluators. Table 5 shows that for all evaluated sensory properties, pasta with 20% of flaxseed was rated lowest (5.03 to 5.51; neither like nor dislike and like slightly) compared to pasta with 10% of flaxseed (6.21 to 6.71; like slightly and like moderately) and pasta with 0% of flaxseed (8.11 to 8.38; like very much) that consumers are accustomed to.

Pasta with flaxseed has worse sensory quality but the stickiness of cooked pasta with flaxseed is good and makes it acceptable for eating (Table 4). Despite all nutritious and healthy alternatives that flaxseed offers to consumers, the addition of flaxseed flour to foods can negatively affect the acceptability of the product, particularly because of the flavour. Specifically, pasta with 20% of flaxseed obtained the lowest score among the samples (5.03) in regard to flavour. This is consistent with the study conducted by Ramcharitar *et al*. (2005), when the addition of flaxseed (11.6%) to muffin formulations also resulted in lower consumer acceptability of the product. Similarly, it was concluded in other studies that the addition of flaxseed in an amount over 10% negatively affected sensory acceptance of croquettes (Hernandez Barros Fuchs 2013), bread (Alpaslan & Hayta 2006), and bagels (Aliani *et al*. 2012).

When considering consumer preferences for pasta sensory properties (e.g. texture) it must be taken into account that those preferences are not universal and vary across the countries/cultures (Kilcast 2004), as well as pasta eating habits (Marti 2016). Also, it is shown that younger consumers prefer firmer textural properties while older consumers are more content with soft pastas (Kilcast 2004). Based on this fact and the obtained scores for overall acceptability of 10 and 20% flaxseed pasta (like moderately and like slightly, respectively), it can be expected that pasta with flaxseed will be accepted by a certain group of consumers.

Table 4. Evaluated sensory properties and overall acceptability of spelt pasta with flaxseed (mean ± SD)

Evaluated properties	Spelt pasta with flaxseed (%)		
	0	10	20
Appearance	8.2409 ± 1.04688	6.7153 ± 1.25410	5.4453 ± 0.98458
Colour	8.1168 ± 0.79581	6.6423 ± 0.94509	5.2701 ± 0.85323
Flavour	8.3869 ± 0.75972	6.4161 ± 0.88818	5.2044 ± 0.54420
Texture	8.2993 ± 0.77994	6.2190 ± 0.70414	5.0365 ± 0.67963
Overall acceptability	8.3650 ± 0.73641	6.5255 ± 1.05775	5.2555 ± 0.72790

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Table 5. Quality of the cooked pasta with flaxseed

	Spelt pasta with flaxseed (%)		
	0	10	20
Volume increase a (%)	3.51 ± 0.41[a]	2.92 ± 0.24[a]	2.75 ± 0.40[b]
Cooking loss R (% DM)	5.0 ± 0.57[a]	7.80 ± 0.73[b]	6.30 ± 0.38[c]
Stickiness*	9.0 ± 0.77[a]	8.0 ± 0.68[a]	7.0 ± 0.87[b]

DM – dry matter; *sensor testing; minimum score is 1, maximum score is 10; results are presented as mean ± SD; different letter within the same row indicate significant differences ($P < 0.05$), according to Tukey's test; number of repetitions: $n = 3$

Additionally, it should be highlighted that consumers tried plain cooked pasta, without any sauces, dressings or seasonings. Since a pasta meal is usually prepared in combination with various food ingredients of dominant flavour (e.g. tomato sauce), the obtained sensory quality scores make a good starting point for a new functional product.

CONCLUSION

Based on the results of the chemical composition, flaxseed flour is chemically different from wholemeal spelt flour and as an addition it can serve to adjust deficit of protein or cellulose in spelt products. Flaxseed flour contains statistically significantly less saturated fatty acids, more linolenic (ω-3), and less linoleic acid (ω-6) in comparison with spelt flour. Flaxseed flour has a favourable balance of ω-6/ω-3 essential fatty acids, which is 1 : 4, while this ratio in wholemeal spelt flour is 20 : 1. The addition of flaxseed flour into spelt pasta in the quantities of 10 and 20% significantly increases the share of ω-3 fatty acids, which results in an improved ratio of ω-6/ω-3 (6.7 : 1 and 1 : 1.2). Daily intake of 100 g of pasta with 20% of flaxseed satisfies the daily need of ω-3 essential fatty acids (5.9 g) that is recommended by ISSFAL.

This research points out that flaxseed flour could be technically used for production of functional pasta product and that sensory characteristics are within the consumer acceptability range. Although pasta with flaxseed differs in terms of sensory quality from conventional pasta consumers are accustomed to, it certainly makes a healthier option. In that regard, further research should examine consumers' attitudes towards the healthfulness of functional pasta product.

Lastly, further technological and sensory improvements are necessary, and that makes a challenge for pasta technologists.

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