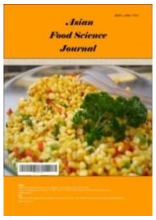

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Comparison of Commercial Gluten Containing and Gluten Free Pastas: Cooking Quality Parameters

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Authors' contributions

This work was carried out in collaboration between both authors. Author OKG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MT managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: Gluten-free food (GFF) consumers reportedly have problems with the lower cooking quality of gluten-free pastas (GFPs) compared to gluten-containing pastas (GCPs). This work is designed to compare the cooking quality of commercial GFPs and GCPs population wise for contributing to the resolution of the issue in the market.

Study Design, Materials and Methodology: Cooking quality parameters of 10 commercial GFPs (maize based and maize-rice based) and 10 commercial GCPs (semolina), namely optimum cooking time (OCT), weight increase (WI), volume increase (VI), cooking loss (CL), and their microstructures were determined.

Results: GCPs had shorter OCT, higher WI and VI, and lower CL than GFPs ($P < .05$), representing higher cooking quality. GCPs showed more consistent cooking quality compared to GFPs. GCPs showed more consistent cooking quality compared to GFPs. GFPs made of maize showed higher cooking quality than GFPs made of maize and rice mixture ($P < .05$). When considering the microstructure, GCPs has a smooth outer surface where the gluten network provides a framework that holds embedded starch granules. On the other hand, GFPs has a protruding surface where gelatinized starch provides a framework that holds embedded protein patches, which results poor cooking quality.

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Conclusion: GCPs shows higher cooking quality compared to GFPs. They also exhibited a narrower range for cooking quality parameters indicating their more consistent behavior than those of GFPs. GFPs made of maize showed higher cooking quality than GFPs made of maize and rice mixture.
Originality/value: To the best of the authors' knowledge, this is the first work comparing the cooking quality of populations of commercial pastas (10 GFPs versus 10 GCPs) and embodied the issue.

Keywords: Gluten-free; commercial pasta; cooking quality; microstructure.

1. INTRODUCTION

In the last few decades, interest on gluten-free foods (GFFs) shows a rising trend due to increasing number of individuals having at least one gluten-linked disorder (mandatory GFF-consumers) and preferring GFFs as a lifestyle for any reason (voluntary GFF-consumers) [1]. GFF-consumption is estimated to expand further due to increasing awareness of gluten-linked disorders and aggressive marketing/selling strategies [2].

The rising trend of GFF-consumption is significantly relevant to pasta. It is one of the most consumed products by GFF-consumers and ordinary consumers due to being cheap, convenient, palatable, nonperishable and healthy. The demand for GFFs has been prompting the food industry to produce gluten-free pastas (GFPs) mimicking quality of gluten-containing pastas (GCPs) [2].

Cooking quality of pasta is the key determinant affecting the consumer perception and decision. Fast cooking, having good stability in boiling water, being well-sized, exhibiting non-sticky appearance and being hard enough for chewing are major cooking quality traits of pasta for the positive consumer perception and decision. From the technological point of view, these parameters are characterized quantitatively by the high cooking quality, namely short cooking time, high weight and volume increase, and low cooking loss during cooking [3].

Cooking quality of pasta is practically determined by cooking tests including optimum cooking time (OCT), weight increase (WI), volume increase (VI) and cooking loss (CL). OCT is the length of cooking time until the white core of pasta disappears to obtain the best textural acceptability. WI and VI, related to the compact matrix of cooked pasta with swollen starch granules entrapped in a coagulated protein network, and significantly affect the appearance of pasta on the plate [4]. CL is related to stickiness/non-stickiness of pasta, and an estimate of pasta resistance against disintegration during boiling [5].

It is reported that commercial GFPs are not still as good as GCPs in terms of cooking quality and do not fulfill the expectations of GFF-consumers [2]. GFF-consumers would like to consume good quality GFPs imitating GCPs well [6]. Though the lower cooking quality of commercial GFPs than that of commercial GCPs is reported, supporting experimental data is scarce. Lucisano et al. [7] are the only ones attempting to compare the cooking quality of commercial pastas, a population of 14 GFPs versus 1 GCP.

The population wise and periodic comparison of GFPs and GCPs would be a good approach to monitor the issue but there is only one work has been done up to date. In this respect, the current work would be cover the lack in this area and its aim is to compare the cooking quality of GFPs and GCPs population wise (10 vs 10) to reveal the current state in the market.

2. MATERIALS AND METHODS

2.1 Materials

Pasta samples were purchased considering ten commercial GC spaghettis (Semolina spaghettis: S1-S10) and ten commercial GF spaghettis (Maize-based spaghettis: M1-4, Maize and rice-based spaghettis: MR1-6), and their diameters were measured using a micrometer. Their contents declared on the packages are as shown in Table 1.

2.2 Methods

2.2.1 Cooking quality tests

Pasta samples were cut at the length of 40 mm for evaluating the cooking quality.

Table 1. Glutenous and GF pasta samples

Sample	Origin	Diameter (mm)	Ingredients (declared on the pack)
			Glutenous
S1	Turkey	1.7	wheat
S2	Turkey	1.7	wheat
S3	Turkey	1.7	wheat
S4	Turkey	1.9	wheat
S5	Turkey	1.9	wheat
S6	Turkey	1.9	wheat
S7	Turkey	1.9	whole wheat
S8	Turkey	1.9	wheat
S9	Turkey	1.9	Wheat
S10	Turkey	1.9	wheat
			Gluten free
M1	Turkey	1.9	maize flour 100 %
M2	Germany	1.7	maize starch, maize flour, chickpea flour
M3	Denmark	1.9	whole maize flour
M4	Romania	1.9	maize flour 100%
MR1	Italy	1.9	maize flour, rice flour, emulsifier: mono and diglycerides of fatty acids
MR2	Italy	1.9	white maize flour (65%), whole maize flour (29.5%), rice flour (5%), emulsifier: mono and diglycerides of fatty acids
MR3	Austria	1.7	maize flour70%, rice flour 29.5%, emulsifier: mono and diglycerides of fatty acids
MR4	France	1.7	maize flour 70%, rice flour 29.5%, emulsifier: mono and diglycerides of fatty acids
MR5	Italy	1.9	maize flour 70%, rice flour 18%, quina 3%, corn starch, emulsifier: E471
MR6	Spain	1.9	maize flour 55%, rice flour 41.5%, quina flour, emulsifier: mono and diglycerides of fatty acids

2.2.1.1 Optimal cooking time

Optimal cooking time (OCT) was determined according to the AACC Approved Method 66-50 [8]. Pasta samples were cooked in boiling distilled water (T=99±1ºC) with pasta/water ratio of 1:10. A sample was removed from the boiling water at every 30 s. The white-opaque core was longitudinally examined by squeezing it between two transparent glass slides. The time required for the white-opaque core to disappear was determined to be OCT.

2.2.1.2 Cooking Loss (CL)

Cooking loss (CL) test was performed according to the AACC Approved Method 66-50 [8]. The moisture content of dry pasta samples (5 g) was first determined at 105ºC to constant mass. Dry pasta samples (25±0.5 g) were cooked in boiling water (250 mL) in a beaker (500 ml) for OCT. The cooked pasta was drained using Buchner funnel and placed in the cooking beaker again. The sample was washed by 90 mL distilled water to take the loose solid on the surface and drained again using Buchner funnel. The volume of water obtained after draining was completed to 350 mL and mixed thoroughly. Then 50 mL of water was transferred to another beaker and dried in an oven at 98ºC to constant mass. The cooking loss was calculated according to the formula 1:

$$CL = (G \times DF) / (100-R) \times 100 \qquad (1)$$

where CL is cooking loss (%); G is the mass difference between beakers before and after the drying (g); DF is dilution factor (350 x 100 / [25 x 50] =28), and R is moisture content of dry pasta (%).

2.2.1.3 Weight Increase (WI)

Weight increase (WI) was determined according to the AACC Approved Method 66-50 [8]. The mass of the cooked and drained pasta from the cooking loss analysis was measured and WI was calculated using the formula 2:

WI= (Mcp - Mdp) / Mdp × 100 (2)

where WI is weight increase (%); Mcp is mass of the cooked pasta (g); Mdp is mass of the dry pasta (25±0.5 g).

2.2.1.4 Volume Increase (VI)

Volume increase (VI) was determined according to the AACC Approved Method 66-50 [8]. Dry pasta (25±0.5 g) was taken into to a graduated cylinder of 250 mL filled with water up to 150 mL mark. The volume of water above 150 mL mark was recorded immediately. The same procedure was used for the cooked and drained pasta from the cooking loss analysis. The volume increase was calculated from formula 3:

VI = (Vcp – Vdp) / Vdp × 100 (3)

where VI is volume increase (%); Vcp: Volume of water above 150 mL mark for the cooked pasta (mL); Vdp: Volume of water above 150 mL mark for the dry pasta (mL).

2.3 Scanning Electron Microscopy (SEM)

GCP and GFP samples were cooked for OCT and lyophilized for the SEM observation. The microstructure of cooked pasta samples was examined through a SEM with a field emission electron gun (FEG) using a secondary electron detector (Zeiss / Supra 55VP, Germany). Each sample was coated with a platinum-palladium alloy in a compact rotary-pumped coating system (Quorum, Q150RS, United Kingdom) before being scanned and photographed at various magnifications.

2.4 Statistical Analysis

Experiments were performed in triplicate, at least two measurements were taken for each experiment (n = 6, at least). Statistical analyses were performed using SPSS version 15.0 (SPSS Inc., Chicago, IL). Analysis of variance (ANOVA) was used when more than one different group was compared as described by Granato, et al. [9], and Duncan's test was performed for deducing statistically significant differences ($P < .05$).

3. RESULTS AND DISCUSSION

3.1 Optimum Cooking Time (OCT)

OCT corresponds to the disappearance time of the white central core of pasta to obtain the best textural acceptability [10]. Fast cooking, namely low OCT is a trait of pasta desired by consumers for the convenience and the good quality perception. OCT of GCPs used in this work resulted in between 9.00±0.0 min (S3) and 12.7±0.5 min (S5), with the average of 11.5±1.1 min (Table 2). Voisey and Larmond [11] long ago showed that OCT for GC spaghetti averaged 13 min for the best textural acceptability. Recently, OCT for GC spaghettis were determined as 12 min by Cubbada et al. [12] and Baiano et al. [13] which are in accordance with our results.

OCT values for GCPs determined in previous works were in close agreement regardless of date, and this work is also in close agreement with them. They are in the textural acceptability range linked to the convenience and the good quality perception. OCT of GFPs resulted in between 9.5±0.0 min (MR3) and 16.7±0.3 (M4) min, with the average of 12.3±2.2 min (Table 2). OCTs reported for GFPs in the literature show a wide range from 3.44 min [14] to 11 min [7]. In this work, GCPs comparatively have shorter OCT and smaller SD values than all GFPs (11.5±1.1 vs 12.3±2.2 min), and a narrower OCT range (9.0–13.0 min vs 9.5–17.0 min). The similar scene is observed in the comparison of OCT of GCPs and GFPs from different sources in the literature [7,15,16]. Accordingly, GCPs have higher quality than GFPs in terms of OCT.

3.2 Weight Increase (WI) and Volume Increase (VI)

WI and VI are measures of water absorption of pasta during cooking. Higher WI and VI values are indicators of the higher quality, and primarily related to the appearance of pasta on the plate [17]. WI of GCPs was between 170±3% (S10), and 210±4% (S2), and averaged 189±11.4% (Table 2). Their VI value was in between 219±22 % (S10) - 271±4% (S6), and averaged 242±22% (Table 2). GCP enables its weight to increase up to 200%, and acquire a palatable and attractive appearance in boiling water while keeping its integrity [18]. Silva et al. [19] reported that a VI value of 200-300% for GCPs is satisfactory. WI and VI values determined for GCPs in this work are comparable with the literature. WI of GFPs was between 145±3% (MR2) and 189±11% (M2) and averaged 155±17% (Table 2). VI of GFPs was between 160±4% (MR1) and 233±13% (M3) and averaged 203±23% (Table 2). Lucisano et al. [7] reported up to 200 % WI and VI for GF spaghettis made of corn, rice, and corn and rice mixture. Results obtained for GFPs in this work are in agreement with the literature. In this work, GCPs significantly have higher average WI and VI values and smaller SD values than GFPs (203±23 vs 242±22% and 155±17 vs 189±11%) (Table 2) (*P* < .05), and narrower WI and VI ranges (167-214% vs 119-202% and 205-277% vs 157-233%). The similar conclusion is drawn from the literature in comparison of WI and VI of GCPs and GFPs [7,12,15]. Accordingly, GCPs have higher quality than GFPs in terms of WI and VI.

3.3 Cooking Loss (CL)

CL represents the resistance of pasta against disintegration during boiling. The lower amount of solid loss into the cooking water points to the higher cooking quality. In terms of CL, pasta is classified as good up to 6 g/100 g, regular between 6 and 8 g/100 g, poor between 8 and 10 g/100 g, and extra poor above 10 g/100 g [20]. CL of GCPs was between 5.4±0.3% (S1) and 6.7±0.5% (S3) and averaged 6.1±0.6% (Table 2). CL values of all GCPs fell into the class of either good or regular. Lucisano et al. [7] also reported that CL values of GCPs did not exceed 6.5% at their optimum cooking time. CL values determined for GCPs in this work are comparable with the literature. In comparison, GFPs showed a dramatically wider range of CL between 3.8±0.7% (MR1) and 14.5±0.5% (MR5), averaging 8.0±3.3% (Table 2). Five out of 10 GFPs (M1, M2, M4, MR3, and MR5) were in the class of either poor or extra poor (Table 2). In the literature, CL values were reported in the range of 3.87±0.03-14.22±0.31% for GFPs made of rice, corn, corn starch, and rice and corn mixture [7]. Results obtained for GFPs in this work are in agreement with the literature. In this work, GCPs significantly have lower average CL and SD values than GFPs (6.1±0.6% vs 7.95±3.3 %) (Table 2), and narrower CL range (5.1-7.3% vs 4.6-15.1%) (*P* < .05). A similar conclusion is obtained from the literature in comparison of CL of GCPs and GFPs [7,19,21]. Accordingly, GCPs have higher quality than GFPs in terms of CL.

Table 2. Cooking quality test results of glutenous and GF pastas

Samples *	Optimum Cooking Time, OCT (min.)	Weight Increase, WI (%)	Volume Increase, VI (%)	Cooking Loss, CL (%)
		Glutenous		
S1	11.1±0.2 $^{c, d}$	193±4 $^{b, c}$	270±12.0 ^{a}	5.4±0.3 ^{e}
S2	12.3±0.3 $^{a, b}$	210±4 ^{a}	260±13 $^{a, b}$	5.9±0.4 $^{c, d, e}$
S3	9.0±0.0 ^{e}	181±6 ^{d}	220±12 $^{d, e}$	6.7±0.5 $^{a, b}$
S4	12.3±0.5 $^{a, b}$	190±3 $^{b, c}$	246±8 $^{b, c}$	6.0±0.2 $^{c, d, e}$
S5	12.7±0.5 ^{a}	195±4 $^{b, c}$	247±15 $^{b, c}$	5.9±0.2 $^{c, d, e}$
S6	11.3±0.5 $^{c, d}$	196±10 ^{b}	271±4 ^{a}	6.9±0.5 ^{a}
S7	12.2±0.3 ^{b}	182±3 ^{d}	226±8 $^{d, e}$	5.7±0.3 $^{d, e}$
S8	11.5±0.0 ^{c}	188±11 $^{c, d}$	235±10 $^{c, d}$	5.9±0.7 $^{c, d}$
S9	11.1±0.1 ^{d}	183±2 ^{d}	224±8 $^{d, e}$	6.2±0.3 $^{c, d}$
S10	11.2±0.3 $^{c, d}$	170±3 ^{e}	219±22 ^{e}	6.4±0.5 $^{b, c}$
		Gluten free		
M1	14.0±0.0 ^{c}	148±1 ^{e}	192±9 ^{f}	8.6±1.5 c, d
M2	13.0±0.0 ^{d}	189±11 ^{a}	228±9 $^{a, b}$	8.6±0.5 c, d
M3	11.7±0.5 ^{e}	166±1 $^{b, c}$	233±13 ^{a}	5.6±0.8 e
M4	16.7±0.3 ^{a}	156 ±2 ^{d}	220±11 $^{b, c}$	11.6±0.7 b
MR1	14.5±0.5 ^{b}	153±3 ^{d}	160±4 ^{h}	3.8±0.7 f
MR2	11.7±0.1 ^{e}	145±3 ^{e}	204±3 $^{d, e}$	7.7±1.4 d
MR3	9.5±0.0 ^{l}	161±4 ^{c}	204±11 $^{d, e}$	9.0±1.1 c
MR4	9.9±0.1 ^{h}	147±1 ^{e}	196±4 $^{e, f}$	5.7±0.2 e
MR5	10.7±0.3 ^{g}	120±2 ^{f}	179±5 ^{g}	14.5±0.5 a
MR6	11.3±0.0 ^{f}	167±2. ^{b}	214±6 $^{c, d}$	4.4±0.0 f
		Mean**		
Glutenous	11.5±1.1 ^{a}	189±11 ^{a}	242±22 ^{a}	6.1±0.6 ^{a}
GF	12.3±2.2 ^{b}	155±17 ^{c}	203±23 ^{c}	8.0±3.3 ^{b}
M	13.8±1.9 ^{c}	165±16 ^{b}	218±19 ^{b}	8.6±2.4 ^{b}
MR	11.3±1.7 ^{a}	149±15 ^{c}	193±20 ^{d}	7.5±3.7 ^{b}

Means with the same superscripts within a column are not significantly different (P > .05)
**n=6; **n=60*

No significant correlation was observed between quality parameters, (such as OCT vs WI, OCT vs VI, OCT vs CL etc.) for neither GCPs nor GFPs (*P* > .05). Maize pasta samples distinctively showed a linear correlation between OCT and CL (R^2=0.9266) that could not be generalized because of insufficient data.

3.4 Comparison of GCPs and GFPs

Comparatively, GCPs showed consistent and high cooking quality, whereas GFPs showed inconsistent and poor cooking quality (*P* < .05) (Table 2). The cooking can be explained by a series of complex phenomena of simultaneous reactions (protein denaturation, starch gelatinization etc.) and transfers (water, heat etc.) analyzed by Sayar et al. [22] for a similar starchy and proteinaceous medium. Protein denaturation and starch gelatinization are the main structure forming phenomena during the cooking, and gluten network is primarily responsible for the cooking quality [21]. Protein denaturation leads to the formation of a continuous and strengthened matrix. The protein matrix traps starch granules, which occlude free interspaces by swelling, and gelatinization gives the unique structure of cooked pasta. Starch and protein transformations occur within the same range of temperature and moisture level. Both of them compete for water, and the swelling of starch granules is antagonistic to protein network formation [23] and vice versa.

If protein denaturation prevails, starch granules hydrate slowly in comparison, and they trap within the protein network resulting in high cooking quality with no stickiness or bulkiness. It can be observed on the micrograph for the GCP sample S1 in Fig. 1. The sample has a smooth clear outer surface where the protein (gluten) network provides a framework holding starch granules embedded. If protein network is not strong and elastic enough, the starch swells and gelatinizes before protein denaturation. In such a case, while amylose losses into the cooking water causing high CL, amylopectin fragments move to the pasta surface causing stickiness and bulkiness giving reduced cooking quality. On the other hand, in the absence of the gluten network, starch provides a weak gel base with protein in it. As observed on the micrographs for GFP samples (MR5 and M3) in Fig. 1, gelatinized starch provides a framework where embedded protein patches are protruding from the surface [4,24]. Due to lack of gluten network, absorbed water cannot be entrapped, and lower WI and VI are obtained. The higher water content (WI and VI) in GCP facilitates the heat transfer rate because of the higher heat diffusivity of water contrary to GFP. Therefore, a higher heat transfer rate in GCPs causes shorter OCT compared to GFPs. In the meantime, swelled starch molecules leave the medium within GFP causing to higher CL.

The narrow ranged cooking quality parameters obtained for GCPs indicate that their manufacture has been standardized thanks to the accumulation of long years' knowledge and experience. Contrarily, comparatively wide ranged cooking quality parameters obtained for GFPs are indicators for the non-standardization.

Efforts for obtaining GFPs mimicking cooking quality of GCPs focus on various sources (maize, rice, sorghum etc.), formulations and processes (hydrostatic pressure, parboiling, extrusion etc.). Even some of them found application in the industry [25,26]. All these promising approaches contribute to improving efforts for producing the higher quality of GFPs [23]. However, as far as the results of this work and the literature are considered, cooking quality of GFPs has not reached that of GCPs yet, and still exhibit wide variation.

3.5 Comparison of GFPs (M vs MR)

The cooking behavior of GFPs was evaluated separately on the basis of their major raw materials (Table 1). The major raw materials of GFPs used in this work are either maize or maize and rice mixture. The most common ingredients in them are proteins, gums, and emulsifiers for mimicking gluten (Table1). Maize pastas (M) showed higher OCT, WI and VI compared to maize and rice mixture pastas (MR) (*P* < .05). No significant difference was observed between them for CL (*P* > .05). Besides, relatively smoother surface (better microstructural organization) was observed in M pastas compared to the MR pastas on the SEM images (Fig. 1). It is reported that the application of rice flour causes low cooking and sensory quality in GFP because of the weak network developed by rice proteins [7,27]. For this reason, emulsifiers are often used in MR pasta formulations (Table 1). M pasta samples exhibited cooking quality parameters somewhere between GCP and MR pasta samples (Table 2). This suggests that aptitude of the raw material and technological processes adopted led to a good level of starch arrangement linked to the higher cooking quality of M pastas [19].

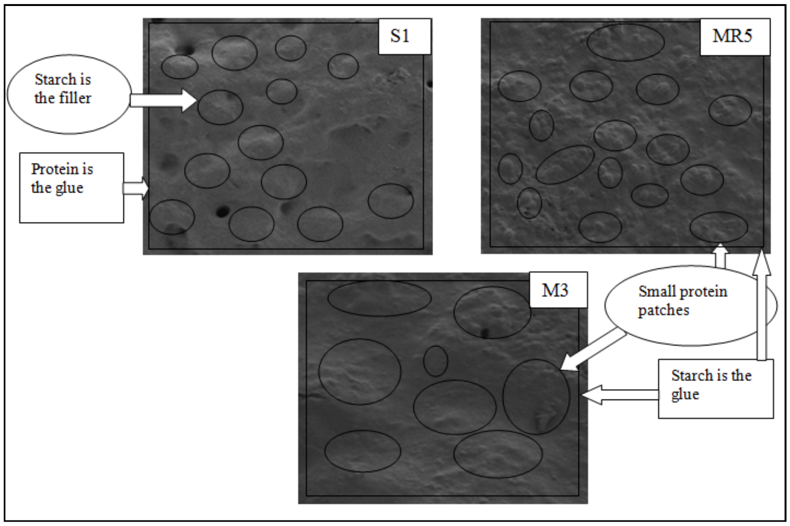

Fig. 1. SEM images of GCPs and GFPs with × 500 magnification

Most works to improve the cooking quality of GFPs adopt an empiric approach focusing on varying ingredients and processing conditions rather than understanding the molecular organization associated with good or poor cooking quality. According to recent studies on GFP production, understanding the relationship between starch structures and processing conditions would help the industry reformulate and develop products with higher cooking quality [28].

Up to date, that of Lucisano et al. [7] is the only work comparing the cooking quality of commercial pastas (14 GFPs versus 1 GCP). The current work is the first one making the comparison between the population of commercial pastas (10 GFPs versus 10 GCPs) to the best knowledge of the authors. Findings of this work showed that GCPs have still higher quality than GFPs in terms of cooking quality. This work suggests that further periodic comparisons of commercial GCPs and GFPs population wise would be helpful to understand the progress in their cooking quality in the future.

4. CONCLUSION

GCPs showed shorter OCT, higher WI and VI, and lower CL, resulting higher cooking quality ($P < .05$) compared to GFPs. They also exhibited a narrower range for cooking quality parameters indicating their more consistent behavior than those of GFPs. GFPs made of maize showed higher cooking quality than GFPs made of maize and rice mixture. Despite various raw materials and processes used by different producers, none of GFPs showed as high cooking quality as GCPs. Further challenges should be focusing on improving the cooking quality GFPs, and periodic comparisons of commercial GCPs and GFPs would be a good approach for this purpose.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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