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Food science at your table: the use of turmeric flour as an antioxidant-rich ingredient to improve healthiness in whole fresh pasta

A ciência de alimentos na sua mesa: o uso da farinha do açafrão como ingrediente rico em antioxidantes para melhoria da saudabilidade em massas frescas integrais

La ciencia de los alimentos en su mesa: el uso de harina de azafrán como ingrediente rico en antioxidantes para mejorar la salubridad de la pasta fresca entera

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Abstract
Fresh pasta with whole wheat flour (WWF) presents healthiness, but the consumer is not used to its consumption, due to the dark color. Therefore, the use of regional ingredients, which may change its color, could be an option to stimulate its use and daily consumption. The objective of this study was to evaluate the technological and antioxidant capacity of the fresh pasta elaborated with 51% WWF (49% Refined Wheat flour - RWF) (Control, M0) and the partial replacement of RWF by turmeric (Curcuma longa) flour (TF) at 3, 6 or 9% (respectively M1, M2 and M3). The data were analyzed by ANOVA and Tukey test (p-value<0.05). Pastes with TF presented yellowish color, longer cooking time, firmness and weight gain compared to M0. M2 presented a significant increase in total phenolics (0.57 µg Gallic Acid equivalent/mg), ABTS (12.21 µmol Trolox equivalent/mg) and DPPH (5.74 µg Trolox equivalent/mg) in relation to M0. The replacement of RWF up to 6% by TF in pastas with 51% of WWF was benefic to change color and increase functional properties, besides increasing the added-value of this tuber and promoting its consumption as healthiness and color ingredient.
Keywords: *Curcuma longa*; Natural colorant; Antioxidant compounds; Healthiness; Sustainability.

Resumo
Massa fresca com farinha de trigo integral (WWF) apresenta saudabilidade, mas o consumidor não está acostumado com seu consumo, devido à cor escura. Portanto, o uso de ingredientes regionais, que podem mudar de cor, pode ser uma opção para estimular seu uso e consumo diário. O objetivo deste estudo foi avaliar a capacidade tecnológica e antioxidante da massa fresca elaborada com 51% WWF (49% Farinha de Trigo Refinado - RWF) (Controle, M0) e a substituição parcial do RWF por farinha de cúrcuma (Curcuma longa) (TF) em 3, 6 ou 9% (respectivamente M1, M2 e

M3). Os dados foram analisados por ANOVA e teste de Tukey (p-valor <0,05). As pastas com TF apresentaram coloração amarelada, maior tempo de cocção, firmeza e ganho de peso em relação ao M0. M2 apresentou aumento significativo de fenólicos totais (0,57 µg equivalente de ácido gálico / mg), ABTS (12,21 µmol equivalente de Trolox / mg) e DPPH (5,74 µg equivalente de Trolox / mg) em relação ao M0. A substituição do RWF em até 6% pelo TF nas massas com 51% do WWF foi benéfica para a mudança de cor e aumento das propriedades funcionais, além de aumentar o valor agregado desse tubérculo e promover seu consumo como ingrediente saudável e corante.
Palavras-chave: *Curcuma longa*; Corante natural; Compostos antioxidantes; Saudabilidade; Sustentabilidade.

Resumen
La pasta fresca con harina integral (WWF) es saludable, pero el consumidor no está acostumbrado a su consumo, debido al color oscuro. Por tanto, el uso de ingredientes regionales, que pueden cambiar de color, puede ser una opción para estimular su uso y consumo diario. El objetivo de este estudio fue evaluar la capacidad tecnológica y antioxidante de la pasta fresca elaborada con 51% de WWF (49% Harina de Trigo Refinada - RWF) (Control, M0) y la sustitución parcial de RWF por harina de cúrcuma (*Curcuma longa*) (TF) en un 3, 6 o 9% (M1, M2 y M3 respectivamente). Los datos fueron analizados por ANOVA y prueba de Tukey (valor de p<0.05). Las pastas con TF mostraron color amarillento, mayor tiempo de cocción, firmeza y ganancia de peso en comparación con M0. M2 mostró un aumento significativo en fenoles totales (0,57 µg equivalente de ácido gálico / mg), ABTS (12,21 µmol equivalente de Trolox / mg) y DPPH (5,74 µg equivalente de Trolox / mg) en comparación con M0. La sustitución de RWF hasta en un 6% por TF en las masas con un 51% de WWF fue beneficiosa para el cambio de color y aumento de las propiedades funcionales, además de incrementar el valor agregado de este tubérculo y promover su consumo como ingrediente saludable y colorante.
Palabras clave: *Curcuma longa*; Colorante natural, Compuestos antioxidantes; Salubridad; Sustentabilidad.

1. Introduction

The COVID-19 pandemic has brought new thinking to food production chains (Hobbs, 2020). Countries in crisis tend to close their markets, putting their food sovereignty at risk and looking for local alternatives to diversify the population's diet, and maintain supply, even during periods of crisis, such as this one (Hoover, 2020). Associated with this search for new flavors and ingredients, science-based cuisine is closely associated with the design of stimulating and innovative dishes that make consumers feel an explosion of sensation (Burgos et al., 2019), while these foods can promote consumer health benefits.

Pasta is a clean-label product with high production and consumption in the world, because it is affordable, easy to find and plays a large role in providing the daily calories required by a person. It is possible to prepare a pasta by only mixing water and wheat flour, even though nowadays the pasta production is more incremented, being prepared with a large number of products, such as vegetables and eggs. Other products that have been used are the tubers, though their properties and nutritional content are scarcely known by most people (Walter et al., 2005).

Unlike countries that use Triticum Durum for pasta production, many countries do not have the climate and soil conditions for this species of wheat, which leads to the import of semolina or the product, promoting unsustainable actions. The production of pasta adapted to the local flavor, valuing regional habits and culture, can promote health, sustainability and be a source of income. Thus, in countries like Brazil, which import wheat, the consumption of whole wheat flour and local ingredients, such as tubers, can be an option that values the local economy and promotes the recovery of cultural habits. The association of wheat produced in the country with tubers grown in abundance, but underutilized by the population, can generate products of greater added value.

The turmeric (Curcuma longa) is native to southwest India and can be found in South American countries as well, having commercial power due to its rhizome that is widely used in medicine, cosmetics and in the food industry. It was initially used as a medicinal herb for indigenous tribes due to its bioactive properties. Nowadays, it has been used in the food industry as a spice and a food ingredient due to its easy digestibility (Kumar et al., 2006). Curcumin, naturally present in turmeric, has shown to possess a wide range of pharmacological activities including anti-inflammatory, antioxidant and anti-cancer effects. In addition, curcumin exhibits strong antioxidant activity, comparable to vitamins C and E (Maheshwari et al., 2006). In fact, according to the research made by Maizura et al. (2009), the turmeric in natura presents 67.89 mg Gallic Acid Equivalent/100 g of sample.

Antioxidants have potential in promoting health and reducing cancer risk, hypertension and heart disease (Valko et al., 2007; Wolfe et al., 2003). Health professionals and consumers have shown interest in using natural antioxidants from plant extracts, worried by the effects that synthetic antioxidants can cause in food (Suhaj, 2006; Sun & Ho, 2005), and consequently, in the human organism.

The aim of this work was to produce fresh pasta with whole grain wheat flour and turmeric flour, to evaluate its technological properties and antioxidant capacity. The elaboration of pasta with turmeric flour, in addition to the 51% whole grain wheat flour, would make it possible obtaining a product with high functional quality, which besides bringing positive benefits to the small farmer, would increase the added value of the product.

2. Methodology

2.1 Material

The turmeric flour was obtained commercially from Cooperaçafrão (Mara Rosa, Goiás). The whole grain wheat was grinded in an experimental mill (Quadrumat Senior, Brabender-Germany) in whole flour. The refined wheat flour was purchased from the same batch in the local market of Campinas (SP).

2.2 Chemical and rheological characterization of raw materials

The whole grain wheat flour (WWF), refined wheat flour (RWF) and turmeric flour (TF) were characterized for proximate composition (moisture, fibers, protein, ash, ether extract and carbohydrate by difference) according to American Association of Cereal Chemists (AACCI, 2010). Farinography (Brabender, Germany) and Extensography (Brabender, Germany) analyses were made in order to determine the force, extensibility, elasticity and water absorption from refined wheat flour and whole grain wheat flour (AACCI, 2010).

2.3 Formulations

Four formulations (M0, M1, M2 e M3) of fresh pasta were elaborated with partial replacement of RWF by TF (0, 3, 6 and 9%), according to Table 1.

2.4 Production of the fresh pasta

The ingredients of each formulation (Table 1) were mixed during 5 min and then 42 mL of water for each 100 g of the total ingredients was added and mixed slowly in a Pastaia II (Italvisa, Brasil) during 20 minutes. The mixture rested for 5 min and then was extruded using a matrix of spaghetti with 1.8 mm internal diameter. At the end of the matrix, the pasta was hung in holders, dried with cold air for one hour and then was packed in low density polyethylene (LDPE), white pigmented with 1,5% titanium dioxide (Plastunion Indústria de Plásticos LTda, Caieiras, Brazil). The packages were sealed, and stored for 24 hours under refrigeration at 10°C, until the analyzes were performed.

Table 1. Formulations of fresh pasta with replacement of refined wheat flour by turmeric flour.

Formulations	%Turmeric flour	% Refined wheat flour	% Whole grain wheat flour
M0	0	49	51
M1	3	46	51
M2	6	43	51
M3	9	40	51

Source: Authors.

2.5 Evaluation of the fresh pasta

The raw fresh spaghetti was evaluated by moisture content (method nº. 44-15A (AACCI, 2010), optimal cooking time (method nº.16-50) (AACCI, 2010), cooking yield (nº. 16-50) (AACCI, 2010) and solid content in the cooking water (nº. 16-50) (AACCI, 2010). The firmness and cutting force were measured by Texturometer (Analyzer TA.XT2, Stable Micro Systems, England) and probe Light Knife Blade (A/LKBF), that is specific for pasta. Color parameters were obtained by Colorimeter (Miniscan XE 3500 Hunterlab, USA) CIE-Lab system with illuminat D65, measuring the L*, a*, b*e o ΔE. L* parameter shows brightness and ranges from 100 (white) to 0 (black), b* parameter refers to the axis that ranges from blue (-b*) to yellow (+b*) and a* parameter refers to the axis that ranges from green (-a*) to red (+a*).

2.6 Selection of the most appropriate raw fresh spaghetti formulation

After the evaluation of the technological parameters, the formulation with addition of turmeric pasta that presented the closest results to M0 formulation, was selected for the antioxidant capacity evaluation. The obtained results for solid content, yield, texture and optimal cooking time were submitted to the analysis of variance (ANOVA) and Tukey test ($p<0.05$) for the average comparison using the statistical program SAS, 9.4 version, licensed by UNICAMP.

2.7 Antioxidant Capacity of selected raw fresh spaghetti formulation

To evaluate the antioxidant capacity, the cooked M0 formulation and the selected cooked pasta were ultrafreezed (UK05B, Klimaquip – Pouso Alegre- Minas Gerais, Brazil), lyophilized (Lp820, Liobras – São Carlos- São Paulo, Brazil), grinded in ball mill and dissolved in methanol to get a 0.5 mg/mL pasta extract solution. The pasta extracts were analyzed according to Folin-Ciocalteu (Total Phenolics), DPPH (Free radical-scavenging activity) and ABTS (radical cation) methodologies.

Total Phenolics was determined using the Folin-Ciocalteu method (Roesler et al., 2007). A 200 µL aliquot of pasta extract was centrifuged at 4900 RPM during 5 min (Baby I 206-BL, Fanem – São Paulo, Brazil) and mixed with 1000 µL of 10-fold diluted Folin-Ciocalteau reagent and 800 µL of 7.5% sodium carbonate solution. After 5 min at 50 °C, absorbance at 760 nm was read in the spectrophotometer DU-640™ (Beckamn-Coulter – Brea, CA, USA). Standard gallic acid concentrations (0.3125 to 50 µg/mL) were used to prepare a calibration curve and the results were expressed as milligrams of gallic acid equivalents (mg GAE/g) in dry basis.

Free radical-scavenging activity (DPPH) was measured using a method adapted by Brand-Williams et al. (1995). The DPPH solution (0.004% w/v) was prepared in methanol and then stored under refrigeration until needed. Absorbance was measured and adjusted to 1.0 ± 0.2 at 517 nm using the spectrophotometer. A standard curve was built with Trolox varying between 25 and 200 µM. An aliquot of 100 µL pasta extract (prepared in item 1.1) and 100 µL of methanol were mixed with 1000 µL of DPPH solution. After 30 min of reaction in a dark place, the absorbance of the remaining DPPH was measured at 517 nm against blank. Results are expressed in µg Trolox Equivalent (TE)/g dried mass.

The radical cation ABTS scavenging capacity was measured using the method described by Re et al. (1999). In brief, ABTS was dissolved in water to a 7 mM concentration. ABTS radical cation (ABTS•) was produced by reacting ABTS stock solution with 2.45 mM potassium persulfate (final concentration) and allowing the mixture to stand in the dark at room temperature for 12–16 h before use. An aliquot of 2 mL of this solution was diluted in 100 mL of ethanol, and adjusted by dilution or concentration to an absorbance of 0.70 ± 0.02 at 734 nm.

Trolox standard curve was prepared by addition of 1000 µL of diluted ABTS• solution to 200 µL of Trolox standards (final concentration 3.125 – 125 µM) in ethanol; the absorbance reading was taken after 6 min. The percentage inhibition of absorbance at 734 nm was calculated and plotted as a function of concentration of Trolox. Similarly, an aliquot of 25 µL pasta extract and 175 µL of ethanol were mixed with 1000 µL of diluted ABTS solution. After 6 min of reaction, the absorbance of the remaining ABTS was measured at 734 nm against blank. Results were expressed in µg Trolox Equivalent (TE)/g dried mass.

2.8 Statistical Analysis

All the data were obtained at least in triplicate, excepting from texture which was analyzed in quintuplicate, and were submitted to the analysis of variance (ANOVA) and Tukey test (p-value<0.05) for the average comparison using the statistical program SAS, 9.4 version, licensed by UNICAMP. The antioxidant capacity was made comparing two samples and according to the F test (p-value<0.05).

3. Results and Discussion

3.1 Chemical and rheological characterization of raw materials

Table 2 shows the proximate composition of WWF, RWF and TF. We can observe that WWF and RWF present composition according to the technical regulation on the identity and quality of wheat flour from Brazil (IN nº 8 of 2005). TF presented a different composition to those obtained by SPINELLO et al. (2014), which observed 3.22% for protein, 5.69% for ether extract, 4.34% for ash and 62.71% for total carbohydrate. This variation in composition can be explained by the origin of the turmeric production, since the soil conditions and the region's climate directly interfere in the final nutrient composition of the tuber.

Table 3 presents the results obtained from farinographic and extensographic analysis for RWF and WWF. The RWF can be classified as a strong flour, according to PRESTON and KILBORN (1984), due to water absorption (W) higher than 58%, dough development time (DDT) between 8 and 10 minutes, stability (S) higher than 15 minutes, and mixing tolerance index (MTI) between 15 and 50. The data for WWF showed higher water absorption, which may indicate a higher pentosans quantity, but the analyses are not able to predict the flour force, given that the fibers interfere in the gluten network development.

Table 2. Proximate composition of the refined wheat, whole grain wheat and turmeric flours.

Samples	Proximate composition % (g/100g)					
	Moisture	**Ash**	**Protein**	**Ether extract**	**Fiber**	**Carbohydrate**
Refined wheat flour	11.60	0.61	12.57	1.48	2.89	73.74
Whole grain wheat flour	13.25	1.36	14.38	2.03	10.38	68.98
Turmeric flour	11.28	6.04	05.48	0.94	20.27	76.26

Source: Authors.

Table 3. Farinography and extensography from refined wheat flour and whole grain wheat flour*.

Parameters			**Refined wheat flour**	**Whole grain wheat flour**
Farinography	W%		61.10	65.10
	AT (min)		01.69	03.08
	DDT (min)		09.71	07.04
	DT (min)		26.24	13.41
	S (min)		24.56	10.33
	MTI		20.67	37.33
Extensography	R (mm)	45(min)	306.50	343
		90(min)	370.50	373.50
		135(min)	345.50	354.50
	E (mm)	45(min)	208.50	113.50
		90(min)	190.50	107.50
		135(min)	193.50	110
	RM (mm)	45(min)	497.50	343.50
		90(min)	564	373.50
		135(min)	537.50	354.50
	R/E	45(min)	1.45	3.05
		90(min)	1.95	3.45
		135(min)	2.30	3.20

	45(min)	141	58.50
A (cm2)	90(min)	146	59
	135(min)	140	57.50
	45(min)	2.40	3.05
Número ratio (max)	90(min)	2.95	3.45
	135(min)	2.80	3.20

*Where: DDT = Dough Development Time; S = Stability; MTI = Mixing Tolerance Index; W%= Water Absorption; AT= Arrival Time; DT= Departure Time; R= Resistance to extension; E= Extensibility; RM= Maximum resistance; R/E= proportional number; A= energy. Source: Authors.

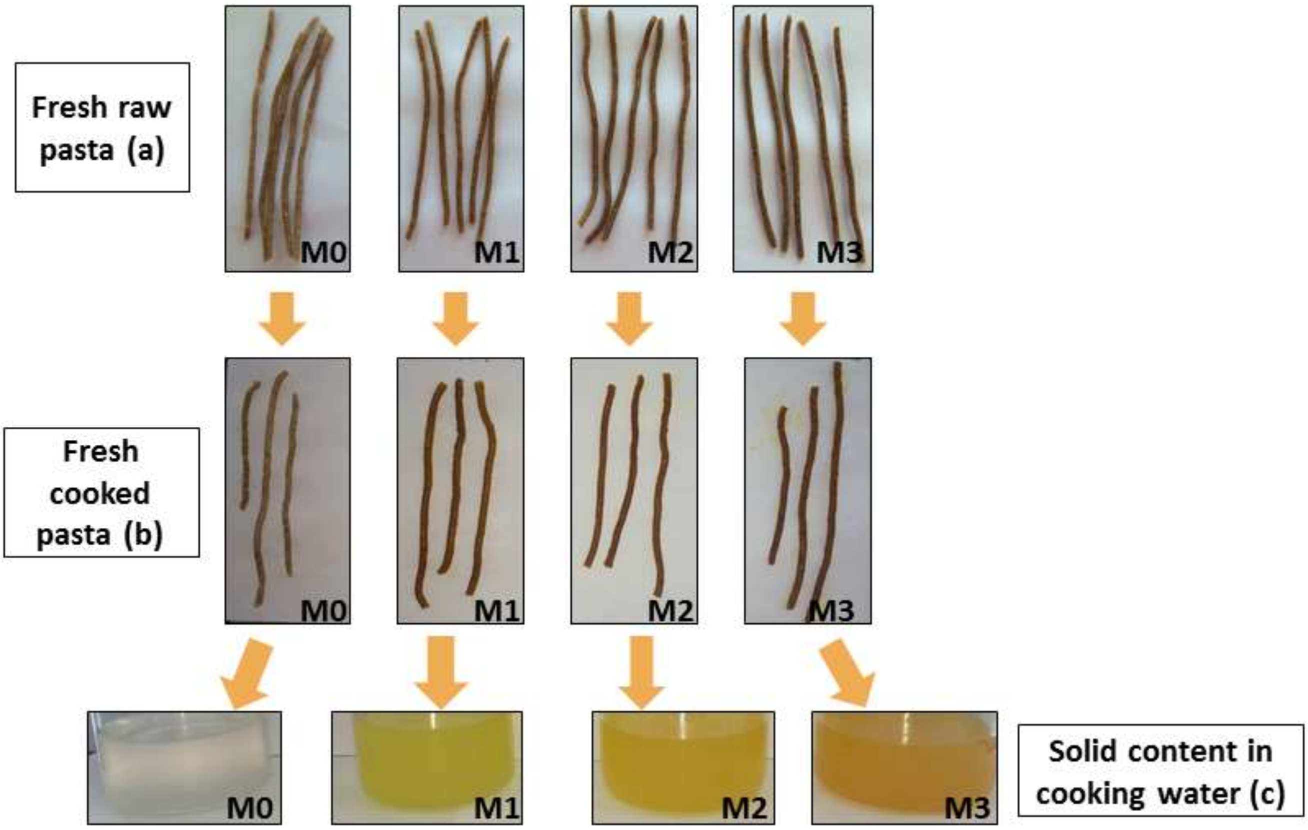
3.2 Evaluation of the fresh pasta

Formulations of fresh raw spaghetti, fresh cooked spaghetti and the cooking water are presented on Figure 1. After cooking the spaghetti samples (b) it was possible to notice an increase in volume from the raw fresh pasta samples due to the water absorption as well as an increase of the yellow color from the cooking water (c) due to water-soluble pigments present in turmeric. The TF-containing-pastas can be also used in soups, for increasing the intake of healthy soluble pigments.

Table 4 presents the results obtained for the raw fresh pasta and cooked fresh pasta. While control pasta showed dark brown color, the pastas containing TF were yellowish, presenting a decrease in L* parameter, with an increase in TF content, increasing color intensity. The b* parameter increased when compared with the M0 formulation. When we analyzed the color difference between the pastas (ΔE), it was possible to verify that M0 was completely different to the samples with TF, even perceptible with the eyes. However, this color difference was not perceptible for samples M1 to M3, because according with TIWARI et al. (2008), the perceivable color differences can be classified as: very distinct, distinct and small difference, when the ΔE value is above 3.0, between 1.5 and 3.0, and below 1.5, respectively. When cooked, the pastas were lighter, due to the water absorption and loss of pigments in the cooking water. However, pastas M1 to M3 continued to be clearly different to M0, which shows that TF effectively contributed to the yellowish color of pastas.

The firmness from raw fresh pastas presented higher values in comparison to the correspondent cooked pastas. Furthermore, the raw pastas with TF were firmer than M0, meaning that they are less prone to breakage during transport, storage and manipulation for cooking, indicating that TF had a technological effect similar to egg, which is added to pastas from *T. aestivum*. In the cooked pastas, the firmness from M0 was equal to M1 and M2, being significantly higher than M3. The loss of firmness in M3 can be directly related to the substitution of RWF by 9% TF, which causes a prejudice in the gluten network formation. The moisture content from the raw fresh pasta formulations was below 35%.

Figure 1. Picture from the formulations (M0, M1, M2 and M3) from fresh raw pasta (a), fresh cooked pasta (b) solid content in cooking water (c), varying the turmeric flour content in three levels of substitution (3, 6 and 9%) for refined wheat flour.



Source: Authors.

The cooking time of fresh pastas is expected to be lower than dry pastas, given their hydration, which eases the starch gelatinization, as occurred in the present study. The cooking time in seconds shows the quality of the pasta since a short cooking time influences the economy for the consumer as well as preserves the overall appearance and nutritional composition of the pasta. However, fresh pastas made with WWF should be kept under refrigeration and under vacuum or modified atmosphere to avoid oxidation processes.

Cooking losses below 8 g/100 g are the limit for acceptable quality described by Dick e Youngs (1988), however, these values refer to pasta made with Triticum durum semolina, which has a strong gluten network and is capable of retaining the gelatinized starch during cooking of the pastas. However, in this study, we used WWF and RWF, which were produced from *T. aestivum* wheat, and so it was already expected that pastas presented a greater loss of soluble solids in the water, since the substitution of RWF by TF, in a formulation that already contains 51 % of WWF, can lead to dilution of gluten and consequently to the weakening of the net, and loss of starch during cooking.

In Brazil most pasta products are produced with RWF from *Triticum aestivum* wheat, however, they present less firmness and shorter cooking time, even when added with eggs, to obtain similar color characteristics to pastas elaborated with flour from Triticum durum wheat. Therefore, turmeric can substitute eggs and give yellowish color to pastas, as already happens with other vegetables, such as carrot and spinach. The elaboration of pasta with flour of T. aestivum is currently sold in the Brazilian market, since internationally pastas are obtained from T. durum. There are few published works that evaluated the quality of pasta elaborated with *T. aestivum*, and due to it, the quality standards are not specified for the loss of soluble solids in water from these types of pasta.

Table 4. Results obtained for raw fresh and cooked spaghetti analyses*.

Formulations		Color				Firmness (N)*	Cooking test			Moisture (%)*
		L*	a*	b*	ΔE		Weight gain (g/100 g)*	Soluble Solids in water (g/100 g)*	Optimal time (s)	
Fresh raw pasta	M0	48.72 ± 0.20A	07.95 ± 0.04C	20.53 ± 0.16B	0	2.81 ± 0.17B	-	-	-	35.06 ± 0.16A
	M1	37.71 ± 0.11B	11.19 ± 0.05B	41.84 ± 0.76A	24.20	5.20 ± 0.45A	-	-	-	34.10 ± 0.36B
	M2	37.82 ± 0.20B	11.49 ± 0.05A	41.44 ± 0.70A	23.84	5.16 ± 0.17A	-	-	-	35.05 ± 0.13A
	M3	37.69 ± 0.04B	11.37 ± 0.07A	42.47 ± 0.73A	24.79	5.27 ± 0.54A	-	-	-	35.24 ± 0.40A
Fresh cooked pasta	M0	45.30 ± 0.95A	07.68 ± 0.05C	19.22 ± 0.09C	0	2.17 ± 0.31A	124.40 ± 8.93CC	03.09 ± 0.04D	50	-
	M1	37.54 ± 0.57B	14.31 ± 0.27B	46.11 ± 1.41A	24.79	2.22 ± 0.23A	135.82 ± 1.83BC	05.01 ± 0.09C	90	-
	M2	33.78 ± 0.09C	16.70 ± 0.13A	40.80 ± 1.85B	26.07	2.28 ± 0.17A	145.55 ± 1.79BA	09.01 ± 0.04B	120	-
	M3	33.73 ± 0.38C	17.08 ± 0.41A	41.44 ± 1.48B	26.76	1.83 ± 0.10B	155.84 ± 2.21AC	11.12 ± 0.08A	180	-

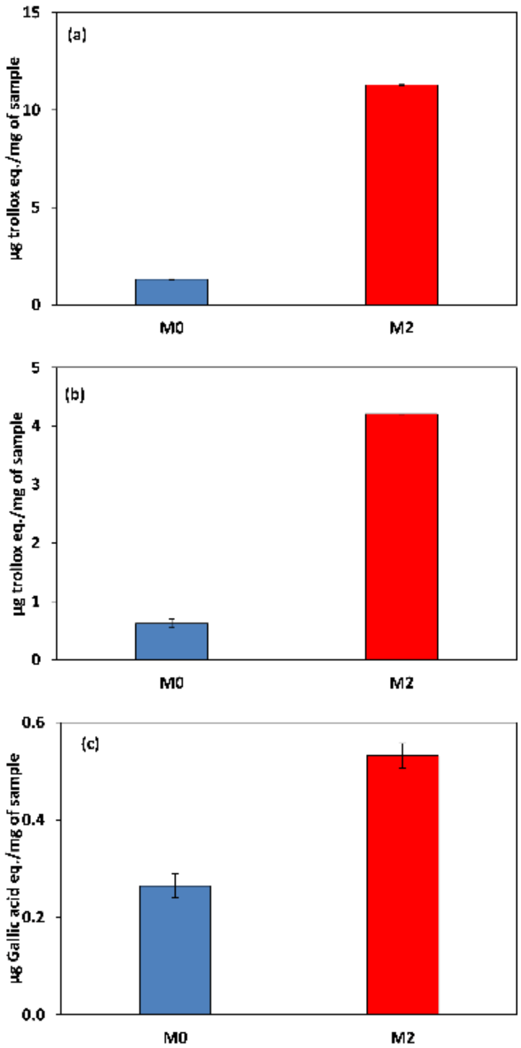
*Mean ± Standard deviation. Means with capital letters in the same column differ significantly from each other by Tukey test (p-value≥0.05).
Source: Authors.

M0 formulation showed the lowest cooking time, compared to the formulations added of TF, and according to the parameters shown in Table 4, it is possible to make pastas replacing RWF by up to 6% of TF, without prejudice to the technological properties of the product. As a combination of factors, M2 formulation was selected for the antioxidant analysis, for being compared to M0.

3.3 Antioxidant Capacity of selected raw fresh spaghetti formulation

Figure 2 presents the results from DPPH, ABTS and total phenolics analyses. The DDPH method consists in the evaluation of the capacity of natural antioxidants to capture free radicals. In this work, it was found an antioxidant capacity 12 times higher in the M2 formulation than in M0, which shows that the turmeric contributed with an antioxidant capacity increase. According to Hirawan et al. (2010) it was found values ranging from 0.19 to 2.32 μM of Trolox Equivalent/g in fresh spaghetti pastas from market.

Figure 2. Antioxidant capacity to DPPH (a), ABTS (b) and Total phenolics (c) from cooked pasta M0 (control with 49% of refined wheat flour and 51% of whole grain wheat flour) and M2 (43% of refined wheat flour, 51% of whole grain wheat flour and 6% of turmeric flour.



Source: Authors.

The ABTS radical is formed due to a chemical, enzymatic or an electrochemical reaction. With this method, it is possible to measure the antioxidant capacity of either hydrophilic or lipophilic compounds (Kuskoski et al., 2005). In this work, it was found a value of 120 µM Equivalent Trolox/100 g of sample, almost 6 times the value found for M0, showing the high turmeric antioxidant capacity.

The Total Phenolic analysis quantifies flavonoids, anthocyanins and phenolic compounds presented in the sample extract. In this study, it was found 0.58 µg of Gallic Acid Equivalent/100 g of sample for the M2 formulation, almost two times the total phenolic content found for the M0 formulation. According to Liu (2007), phenolic compounds in cereal grains are naturally found in conjugated form, and they need to be hydrolyzed for evaluation. In this study, the method used was free phenolics, and the purpose was the evaluation of the increase in the antioxidant capacity by TF addition. Due to the fact that this evaluation was done on cooked pasta, and many soluble pigments were lost into cooking water, the value found in this work corresponds only to free phenolics in pastas.

According to the results obtained for all the three analyses, it is possible to recognize that the turmeric, even in the form of flour, is rich in antioxidant properties and it can show technological and health benefits when substituting RWF in pastas containing 51% from WWF. This means that additional from the functional benefits obtained by the use of whole grain wheat, it is also possible to improve the pastas color, which was observed more yellowish and with more bioactive compounds with the addition of up to 6% of TF.

4. Conclusion

This study showed that it is possible to replace the RWF by up to 6% TF in pastas formulations containing 51% of WWF, due to the improvement of pasta color, texture, yield and antioxidant properties. In this way, the use of colored tuber flours, which can be produced by cooperatives, can have their added value increased as we expand their use to industrially produced pastas consumed in the main meals.

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References

AACCI. (2010). Approved Methods of Analysis. AACC International.

Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. LWT - *Food Science and Technology*, 28(1), 25–30. https://doi.org/10.1016/S0023-6438(95)80008-5

Burgos, V. E., López, E. P., Goldner, M. C., & Del Castillo, V. C. (2019). Physicochemical characterization and consumer response to new Andean ingredients-based fresh pasta: Gnocchi. *International Journal of Gastronomy and Food Science*, 16(February). https://doi.org/10.1016/j.ijgfs.2019.100142

Dick, J. W., & Youngs, V. L. (1988). Evaluation of durum wheat, semolina, and pasta in the United States. In G. Fabriani & C. Lintas (Eds.), Durum wheat: chemistry and technology (pp. 237–248). American Association of Cereal Chemists.

Hirawan, R., Ser, W. Y., Arntfield, S. D., & Beta, T. (2010). Antioxidant properties of commercial, regular- and whole-wheat spaghetti. *Food Chemistry*, 119(1), 258–264. https://doi.org/10.1016/j.foodchem.2009.06.022

Hobbs, J. E. (2020). Food supply chains during the COVID-19 pandemic. *Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie*, cjag.12237. https://doi.org/10.1111/cjag.12237

Hoover, E. (2020). Native food systems impacted by COVID. Agriculture and Human Values. https://doi.org/10.1007/s10460-020-10089-7

Kumar, G. S., Nayaka, H., Dharmesh, S. M., & Salimath, P. V. (2006). Free and bound phenolic antioxidants in amla (*Emblica officinalis*) and turmeric (Curcuma longa). *Journal of Food Composition and Analysis*, 19(5), 446–452. https://doi.org/10.1016/j.jfca.2005.12.015

Kuskoski, E. M., Asuero, A. G., Troncoso, A. M., Mancini-Filho, J., & Fett, R. (2005). Aplicación de diversos métodos químicos para determinar actividad antioxidante en pulpa de frutos. *Ciência e Tecnologia de Alimentos*, 25(4), 726–732. https://doi.org/10.1590/S0101-20612005000400016

Liu, R. H. (2007). Whole grain phytochemicals and health. *Journal of Cereal Science*, 46(3), 207–219. https://doi.org/10.1016/j.jcs.2007.06.010

Maheshwari, R. K., Singh, A. K., Gaddipati, J., & Srimal, R. C. (2006). Multiple biological activities of curcumin: A short review. *Life Sciences*, 78(18), 2081–2087. https://doi.org/10.1016/j.lfs.2005.12.007

Maizura, M., Aminah, A., & Wan Aida, W. M. (2009). Total phenolic content and antioxidant activity of kesum (*Polygonum minus*), ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) extract. *International Food Research Journal*, 17, 45–53.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine*, 26(9–10), 1231–1237. https://doi.org/10.1016/S0891-5849(98)00315-3

Roesler, R., Catharino, R. R., Malta, L. G., Eberlin, M. N., & Pastore, G. (2007). Antioxidant activity of *Annona crassiflora*: Characterization of major components by electrospray ionization mass spectrometry. *Food Chemistry*, 104(3), 1048–1054. https://doi.org/10.1016/j.foodchem.2007.01.017

Suhaj, M. (2006). Spice antioxidants isolation and their antiradical activity: a review. *Journal of Food Composition and Analysis*, 19(6–7), 531–537. https://doi.org/10.1016/j.jfca.2004.11.005

Sun, T., & Ho, C.-T. (2005). Antioxidant activities of buckwheat extracts. Food Chemistry, 90(4), 743–749. https://doi.org/10.1016/j.foodchem.2004.04.035

Valko, M., Leibfritz, D., Moncol, J., Cronin, M. T. D., Mazur, M., & Telser, J. (2007). Free radicals and antioxidants in normal physiological functions and human disease. *The International Journal of Biochemistry & Cell Biology*, 39(1), 44–84. https://doi.org/10.1016/j.biocel.2006.07.001

Walter, M., Silva, L. P. da, & Emanuelli, T. (2005). Amido resistente: características físico-químicas, propriedades fisiológicas e metodologias de quantificação. *Ciência Rural*, 35(4), 974–980. https://doi.org/10.1590/S0103-84782005000400041

Wolfe, K., Wu, X., & Liu, R. H. (2003). Antioxidant Activity of Apple Peels. *Journal of Agricultural and Food Chemistry*, 51(3), 609–614. https://doi.org/10.1021/jf020782a