UNIVERSIDADE ESTADUAL DE CAMPINAS
FACULDADE DE ENGENHARIA DE ALIMENTOS

ADRIANA LUCIA WAHANIK DURAN

WHOLE GRAIN WHEAT PASTA WITH ADDITION OF SOURCES OF BIOACTIVE COMPOUNDS AND NATURAL COLOR MODIFIERS

MASSA ALIMENTÍCIA DE TRIGO DE GRÃO INTEIRO COM ADIÇÃO DE FONTES DE COMPOSTOS BIOATIVOS E MODIFICADORES NATURAIS DE COR

CAMPINAS

2016

ADRIANA LUCIA WAHANIK DURAN

WHOLE GRAIN WHEAT PASTA WITH ADDITION OF SOURCES OF BIOACTIVE COMPOUNDS AND NATURAL COLOR MODIFIERS

MASSA ALIMENTÍCIA DE TRIGO DE GRÃO INTEIRO COM ADIÇÃO DE FONTES DE COMPOSTOS BIOATIVOS E MODIFICADORES NATURAIS DE COR

Dissertação apresentada à Faculdade de Engenharia de Alimentos da Universidade Estadual de Campinas como parte dos requisitos exigidos para a obtenção do título de Mestra em Tecnologia de Alimentos

Dissertation presented to the Faculty of Food Engineering of the University of Campinas in partial fulfillment of the requirements for the degree of Master in Food Technology

Supervisor/ Orientador: Profa. Dra. Maria Teresa Pedrosa Silva Clerici

Co-Supervisor/ Coorientador: Prof. Dr. Yoon Kil Chang

ESTE EXEMPLAR CORRESPONDE À VERSÃO FINAL DA DISSERTAÇÃO DEFENDIDA PELA ALUNA ADRIANA LUCIA WAHANIK DURAN, E ORIENTADA PELA PROFA. DRA. MARIA TERESA PEDROSA SILVA CLERICI

CAMPINAS

2016

Agência(s) de fomento e nº(s) de processo(s): CNPq, 132392/2014-3

Ficha catalográfica
Universidade Estadual de Campinas
Biblioteca da Faculdade de Engenharia de Alimentos
Claudia Aparecida Romano - CRB 8/5816

W125w

Wahanik Duran, Adriana Lucia, 1985-
Whole grain wheat pasta with addition of sources of bioactive compounds and natural color modifiers / Adriana Lucia Wahanik Duran. – Campinas, SP : [s.n.], 2016.

Orientador: Maria Teresa Pedrosa Silva Clerici.
Coorientador: Yoon Kil Chang.
Dissertação (mestrado) – Universidade Estadual de Campinas, Faculdade de Engenharia de Alimentos.

1. Massas alimentícias. 2. Trigo. 3. Tubérculos. 4. Fibra alimentar. 5. Antioxidantes. I. Clerici, Maria Teresa Pedrosa Silva. II. Chang, Yoon Kil. III. Universidade Estadual de Campinas. Faculdade de Engenharia de Alimentos. IV. Título.

Informações para Biblioteca Digital

Título em outro idioma: Massa alimentícia de trigo de grão inteiro com adição de fontes de compostos bioativos e modificadores naturais de cor
Palavras-chave em inglês:
Pasta
Wheat
Tubers
Dietary fiber
Antioxidants
Área de concentração: Tecnologia de Alimentos
Titulação: Mestra em Tecnologia de Alimentos
Banca examinadora:
Maria Teresa Pedrosa Silva Clerici [Orientador]
Elizabeth Harumi Nabeshima
Célia Maria Landi Franco
Data de defesa: 07-03-2016
Programa de Pós-Graduação: Tecnologia de Alimentos

COMISSÃO EXAMINADORA

Profa. Dra. Maria Teresa Pedrosa Silva Clerici (Supervisor)

Universidade Estadual de Campinas-UNICAMP

Profa. Dra. Celia Maria Landi Franco (Membro titular)

Universidade Estadual Paulista "Júlio de Mesquita Filho"- UNESP

Profa. Dra. Elizabeth Harumi Nabeshima (Membro titular)

Instituto de Tecnologia de Alimentos-ITAL

Profa. Dra. Caroline Joy Steel (Membro suplente)

Universidade Estadual de Campinas-UNICAMP

Profa. Dra. Helena Teixeira Godoy (Membro suplente)

Universidade Estadual de Campinas

A Ata da defesa com as respectivas assinaturas dos membros encontra-se no processo de vida acadêmica da aluna.

DEDICATÓRIA

To God, who has given me the precious gift of life and takes
care constantly of me; without Him, nothing would be possible.

To my parents, Hans and Esther Lucía, whose love and
teachings accompany and guide me through life.

To my siblings and family, with whom I can always count on.

"*Not all of us can do great things. But we can do small things with great love.*"
Mother Theresa

AGRADECIMENTOS

I am infinitely grateful to God, for the life, the family, and the friends He has given me.

I thank my parents, Hans and Esther Lucía, their company and support have helped me to overcome difficulties and to give my best effort at every moment. I also thank my siblings and their families, Catherine, Johanna, Francis, Christian, Helmut, María José and Sophie Marie, for their guidance and good example.

I am grateful to Professor Maria Teresa Pedrosa Silva Clerici, for her dedication and indications over these two years; to Professor Yoon Kil Chang, for his guidance and valuable recommendations; to Professor Caroline Joy Steel, for facilitating the work at the Laboratory of Cereals, roots and tubers, and to the professors of the examination committee, for their valuable corrections and indications on this dissertation.

I am also thankful to Alessandra Silva Coelho and Márcio Schmiele, from the Laboratory of Cereals, roots and tubers, to Bianca Wopereis, from Central support laboratory, and to Juliana Campos Hashimoto, from Instrumentation laboratory, for their valuable collaboration at experimental stage. I am thankful with Professor Gláucia Maria Pastore and Angélica Neri-Numa, for their help in pastas antioxidant analysis.

My sincere thanks to my friends and post-grad colleagues in cereals´ field, Mária, Ludmilla, Thaísa, Michele, Ulliana, Amanda, Fernanda, Lara, Geórgia and Flávio, for their company, help, and good humor at difficult moments. To interns Nathanny, Nayara and Igor, your help was very important.

To my friends from *Centro Cultural Altavila*, thank you for your friendship, company and good examples. More than my house in Campinas, you will always be my family in Brazil.

I am grateful to *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq), for the master scholarship. I thank the *Universidade Estadual de Campinas*, the School of Food Engineering, and the Food Technology Department, for the opportunity of my professional education. I thank all the people that in any form collaborated for the development of this work, my sincere **thank you very much!**

RESUMO

A massa alimentícia de farinha de trigo de grão inteiro é rica em compostos funcionais, mas apresenta cor escura e características de cozimento alteradas. Este estudo teve como objetivo a avaliação dos efeitos da adição de concentrados naturais comercialmente disponíveis, amarelo (YNC) e rosa (PNC), assim como também produtos regionais, farinha de cúrcuma (TF) e de batata doce roxa (SPF), em massa fresca de trigo de grão inteiro, nas suas propriedades nutricionais, tecnológicas e antioxidantes. Para a preparação das massas, foi utilizado farinha de trigo de grão inteiro (WGF), farinha de trigo refinada (RWF), YNC e PNC, TF e SPF. Foi feita uma massa controle, contendo WGF e RWF, sendo CP1 a CP3. Para cada set de massa colorida com concentrados naturais ou farinhas de tubérculos realizou-se um delineamento experimental linear 2^2 com três replicatas no ponto central (0,0). A análise de componentes principais (ACP) para os parâmetros de qualidade de aumento de peso, perda de sólidos e textura (firmeza) foi usada para selecionar uma formulação de cada delineamento com características tecnológicas semelhantes; as massas selecionadas foram analisadas quanto às composições centesimais e propriedades antioxidantes.

Os concentrados naturais coloridos (YNC e PNC) efetivamente modificaram a cor das massas de grão inteiro, sem alterar suas características tecnológicas. Deste grupo de massas foram selecionadas uma massa controle (CP), massa amarela (YP1, 60:40 WGF:RWF w:w, 1 g YNC/100 g) e massa rosa (PP9, 70:30 WGF:RWF w:w, 1 g PNC/100 g), que apresentaram textura, aumento de peso e perdas no cozimento semelhantes. As três massas tiveram alto conteúdo de fibra alimentar (6,64 a 7,31 g/100 g). Adicionalmente, PP9 teve um conteúdo de fenólicos totais significativamente maior na massa crua e na cozida (crua PP9: 121,28 µg GAE/g, cozida PP9: 104,03 µg GAE/g) que CP e YP1.

As massas tricolor com adição de farinha de tubérculos selecionadas foram CP3 (70:30 WGF:RWF w:w), massa de cúrcuma (TP6, 60:40 WGF:RWF w:w, 5 g TF/100 g) e massa de batata doce roxa (SPP13, 60:40 WGF:RWF w:w, 9 g SPF/100 g), com propriedades tecnológicas semelhantes e alto conteúdo médio de fibra alimentar (7,92 g/100 g). TP6 apresentou o maior conteúdo de fenólicos totais (534,46 ± 1,93 µg GAE/g), DPPH (5,70 ± 0,10 mg TE/g), e ABTS (9,02 ± 0,58 mg TE/g), com alta retenção (superior ao 98%) da capacidade antioxidante após o cozimento.

Neste estudo foram obtidas massas de boa qualidade tecnológica, nutricional e de propriedades antioxidantes, sendo que os concentrados coloridos naturais são uma alternativa para modificar a cor da massa de trigo de grão inteiro com valor funcional, tornando-a saudável e de rótulo limpo, enquanto a combinação de tubérculos e trigo inteiro pode trazer benefícios à saúde e ser uma alternativa para a sustentabilidade ambiental e com impacto agrícola positivo, para a valorização de culturas regionais.

ABSTRACT

Whole wheat pasta is rich in functional components, but it presents dark color and altered cooking characteristics. This study aimed to evaluate the effects of the addition of yellow (YNC) and pink (PNC) natural concentrates, as well as regional products turmeric flour (TF) and purple sweet potato flour (SPF) to fresh whole wheat pasta, on its nutritional, technological and antioxidant properties. For pasta production were used whole grain wheat flour (WGF), refined wheat flour (RWF), YNC and PNC, TF and SPF. For each set of colored pasta with natural colorants or tuber flours was followed a linear 2^2 experimental design with three replicates at the central point (0, 0). Principal Components Analysis (PCA) for parameters weight gain, solids loss and texture (firmness) was used for selecting one formulation from each set with similar technological characteristics between them; selected pastas were further analyzed for their proximate composition and antioxidant properties.

The natural colored concentrates (YNC and PNC) effectively modified whole wheat pastas color, without altering their technological characteristics. From this group of pastas, a control pasta (CP, 70:30 WGF:RWF w:w), yellow pasta (YP1, 60:40 WGF:RWF w:w, 1 g YNC/100 g) and pink pasta (PP9, 70:30 WGF:RWF w:w, 1 g PNC/100 g) were selected, as they presented similar texture, weight gain and cooking loss, for evaluation of antioxidant capacity. The three pastas had high fiber content (6.64 to 7.31 g/100 g). Additionally, PP9 had significantly higher total phenolics content in raw and cooked whole wheat pasta (raw PP9: 121.28 µg GAE/g, cooked PP9: 104.03 µg GAE/g), in comparison with CP and YP1.

We also selected three pastas with tuber flour addition, which were CP3 (70:30 WGF:RWF w:w), turmeric pasta (TP6, 60:40 WGF:RWF w:w, 5 g TF/100 g) and purple sweet potato pasta (SPP13, 60:40 WGF:RWF w:w, 9 g SPF/100 g), with similar technological properties and high average dietary fiber content (7.92 g/100 g), for evaluation of antioxidant capacity. From the three pastas, TP6 presented the highest total phenolics content (534.46 ± 1.93 µg GAE / g), DPPH (5.70 ± 0.10 mg TE/ g), and ABTS (9.02 ± 0.58 mg TE/ g), with high retention (superior to 98%) of antioxidant capacity after cooking.

In this study were obtained pastas with good technological, nutritional and antioxidant properties, being the natural colored concentrates an alternative for modifying the color of whole wheat pasta while adding functional value to it, making it healthy and *clean-label*, while the combination of tubers and whole wheat can provide health benefits and be an alternative with environmental sustainability and agricultural positive impact, for increasing the value of regional cultures.

CONTENTS

INTRODUCTION

In the last years, there has been an increased concern about the prevention of chronic diseases as well as non-communicable diseases (NCDs). One of the generating factors is an unhealthy diet, low in whole grains, fruits and vegetables, with consequences such as an increase in blood pressure, occurrence of overweight/obesity, hyperglycemia and hyperlipidemia. A higher consumption of whole grains, dietary fiber and antioxidant-rich foods, as well as low glycemic index (GI) foods can bring benefits and reduce the risk of some diseases.

Pasta is a world-wide consumed product that presents convenience and low price for the consumer, with a market in Brazil of approximately seven thousand million BRL (ABIMA, 2014). Pasta has been thought as an excellent vehicle for the inclusion of fibers and functional substances, such as whole grains and roots and tubers flours, which may provide not only dietary fiber, but also phenolic compounds, carotenoids, anthocyanins, and other types of antioxidants.

Whole wheat pasta has already been produced, but presents several inconveniences, such as dark color and altered texture and cooking characteristics (Manthey, 2002). As an alternative, the present project aims to follow two paths: first, the addition of natural colored concentrates to whole wheat pasta, and second, the incorporation of purple sweet potato and turmeric flours to whole wheat pasta, in order to produce a colored, fiber- and antioxidant-rich food.

Therefore, the first article will review the principal advances in functional pasta development, with health benefits for consumers. The second article will present the development of yellow and pink whole wheat pastas, containing commercially-available natural colored concentrates. In the third article, turmeric and purple sweet potato flours represent new sources of fiber and antioxidant compounds for whole wheat pasta, as well as being alternatives that promote agricultural business and sustainability. Evaluations of nutritional and technological properties of the pastas, as well as antioxidant tests, are included in the analysis of the pastas developed in the second and third articles.

OBJECTIVE

2.1 General objective

Develop whole wheat pasta that provides functional benefits for consumers, using natural colored concentrates, purple sweet potato, and turmeric flours.

2.2 Specific objectives

- Review the state of the art of the research and development of functional pastas, as well as indicate the paths for using the beneficial ingredients in an effective and whole approach.
- Develop, using an experimental design, formulations for
  - yellow and pink whole wheat pasta with natural colored concentrates;
  - yellow and purple whole wheat pasta with turmeric and purple sweet potato flours;
- Evaluate the developed products for their technological characteristics;
- Analyze the effects of the variation of the ingredients on the technological properties, by means of the Response Surface Methodology;
- Select optimal formulations for pasta, using Principal Components Analysis;
- Characterize the antioxidant profile and proximate composition of the selected samples of colored and control whole wheat pasta.

FIRST ARTICLE: HOW TO MAKE PASTAS HEALTHIER?

Adriana Lucia Wahanik, Maria Teresa Pedrosa Silva Clerici, Yoon Kil Chang

Article submitted to "*Food Reviews International*"

HOW TO MAKE PASTAS HEALTHIER?

Adriana Lucia Wahanik, Maria Teresa Pedrosa Silva Clerici*, Yoon Kil Chang

Department of Food Technology, School of Food Engineering, University of Campinas (UNICAMP), Campinas, São Paulo, Brazil

**Corresponding author. Tel.: +55 19 3521 4000, E-mail address:mclerici@unicamp.br*

Abstract

Pasta is a world-wide produced and consumed food, which presents convenience and low price for consumers; by the addition of various ingredients, pasta could turn into a functional food with health benefits. Some of these ingredients include whole grains, dietary fiber and antioxidant-rich foods, which have been studied and related to a reduced risk for some non-communicable diseases. In this review, we present the state of the art of the research and development of functional pastas, as well as indicate the paths to use the beneficial ingredients in an effective and whole approach.

Keywords: healthiness, non-communicable diseases, whole grain, dietary fiber, antioxidant properties

1. Introduction

Pasta is a world-wide produced and consumed food, with Italy as the most important producer and consumer (Table 1) (IPO, 2013). Traditionally, pasta is prepared only with durum wheat (*Triticum durum*) and water, because of the hardness, gluten quality and color of this grain. However, due to its higher price and lower supply compared to hard or soft wheat, many countries produce pasta from whole or refined *Triticum aestivum* (Kill & Turnbull, 2001; Wiseman, 2001).

Table 2 shows the nutritional values for cooked refined and whole wheat spaghetti. With similar results in terms of protein and fat, whole pasta has higher fiber than refined pasta, being this beneficial for our health. Since 1949 pasta was approved for enrichment with vitamins and iron by the FDA (Chillo, Laverse, Falcone, Protopapa, & Nobile, 2008), and due to the fact that its consumption is linked to the main meals, pasta has been selected for inclusion of health-beneficial ingredients, for contributing to reduce the risk of non-communicable diseases (NCDs).

Table 1. Pasta world producers and consumers

Top pasta world producers (2013) [a]	ton	*Triticum durum* producer? [b]	Top world pasta consumers (2013) [a]	kg per capita	*Triticum durum* producer? [b]
1. Italy	3,408,499	→Yes	1. Italy	25.3	→Yes
2. USA	2,000,000	→Yes	2. Tunisia	16.0	→Yes
3. Brazil	1,204,900	→No	3.Venezuela	12.2	→No
4. Russia	1,083,000	→Yes	4. Greece	11.5	→Yes
5. Iran	560,000	→No	5. Switzerland	9.2	→No

[a] IPO Survey (IPO, 2013).
[b] Pataco et al. (2015).

Table 2. Nutritional values for cooked pasta (per 100 g)*

Pasta type	Water (g)	Protein (g)	Fat (g)	Ash (g)	Digestible Carbohydrates (g)	Dietary fiber (g)	Energy value (kcal)
Spaghetti (refined wheat, cooked)	62.13	5.80	0.93	0.27	30.86	1.8	158
Spaghetti (whole wheat, cooked)	61.8	5.99	1.71	0.44	30.07	3.9	149

* Source: USDA Agricultural Research Service (2015).

According to WHO report for 2014, 68% of all death causes between 2000 and 2012 were related to non-communicable diseases (NCDs), including cardiovascular diseases, cancers, respiratory diseases, and diabetes (WHO, 2014a). Statistical data show that NCDs have increased and will continue increasing in low and middle-income countries; this trend is caused by growing societies, rapid unplanned urbanization and increasingly sedentary lives (Habib & Saha, 2010; Wagner & Brath, 2012). Besides from mortality rates, NCDs also generate high costs for public health, being the cause of disabilities, hospitalizations, job absences, and extremities amputations, among others (Beaglehole et al., 2011). Some solutions to reduce the risk of NCDs are limiting the energy intake from total fats and sugars, as well as increasing the consumption of fruit, vegetables, legumes, whole grains and nuts, and practicing a regular physical activity (WHO, 2014b).

Several authors have done reviews in the topic of functional pasta (Bustos, Perez, & Leon, 2015; Fuad & Prabhasankar, 2010; Krishnan & Prabhasankar, 2012; Li, Zhu, Guo, Brijs, & Zhou, 2014), both with or without gluten, since this food has an important participation in the world diet, but not much has been said about whole wheat pastas with new ingredients addition, that may modify their technological and sensory properties for increasing their consumption.

The aim of this review is to expose the principal advances done in the development of traditional and whole grain pastas, containing fiber, antioxidant compounds, and various ingredients, with their effects on the technological and functional characteristics of pasta, for producing a healthier food. The future prospective is also discussed, as well as new trends to be explored.

2. Pasta and health

Pasta is obtained from minimum two ingredients: wheat flour or semolina, and water; in some cases, potato flour, maize flour, eggs, natural colorants and vitamins can be added. Pasta can be produced by extrusion or lamination, optionally followed by drying at different time and temperature conditions, and finally it is packaged (Kill & Turnbull, 2001). Pasta can be sold fresh, dry or ready to eat, being the greater percent of it dry pasta, followed by fresh pasta, and last, ready to eat; however, dry pasta is considered more convenient and cheaper for the retailer and the consumer, which causes its predominance in the market (Kill & Turnbull, 2001).

Nutritionally, cooked pasta is a good source of carbohydrates and energy (Table 2), as it contains approximately 30 g of carbohydrates/100 g of pasta (wet basis). However, its low fiber and protein contents indicate the need to supply these nutrients by the addition of other ingredients. Additionally, compared to refined wheat bread, pasta presents a lower glycemic index, which makes it a potential food for ingredient inclusion that may increase satiety, as a consequence from the slow digestibility of the carbohydrates (more than 2 hours) (Brennan, 2008).

For making pastas healthier, we will base our research in the concept defined by Menrad (2003): “Functional foods are not intended only to satisfy hunger and provide humans with necessary nutrients, but also to prevent nutrition-related diseases and increase physical and mental well-being of consumers." Therefore, ingredient addition to pasta must have functional claims, like the ones associated to fibers, antioxidant compounds, proteins, among others, in pure form or as composite flours; however, care must be taken, because the inclusion of ingredients may alter pasta color and structure, affecting also cooking properties and final product texture (Brennan 2008).

Following, we will review some of the studies done in the effort of obtaining healthy pasta, which fulfills technological parameters. Considering the studies from the last 5 years, fibers are the most used ingredient, followed by antioxidant compounds, for improving pasta healthiness. This fact is related to a greater supply of by-products from processing, e.g. defatted flours, fruits peels, waste from juice extraction, or the use of whole grains and their brans, which increase the variety of available functional compounds.

2.1 Glycemic index and fiber in pastas

Glycemic index (GI) determination is a method adopted to rank carbohydrates in the way the blood glucose responds to them when they are consumed (Patil, 2008). Firstly developed by Jenkins et al. (1981), the method measures blood glucose levels of individuals 2 hours after the ingestion of a food, and expresses it as a percent of the response of the same individual to the consumption of a defined quantity of glucose or of refined wheat bread (Patil, 2008). On a 100-basis for glucose, foods can be classified as low-GI (55 or less), intermediate-GI (between 56 and 69) or high-GI (70 or greater) foods (Atkinson, Foster-Powell, & Brand-Miller, 2008). However, GI values depend on the consumer, source and type of food, as well as processing. For example, depending on the level of starch gelatinization, a cereal-based product can have a different GI when cooked at different temperatures (Patil, 2008). The use of whole grain, bran and other sources of fiber in foods had been an alternative for the decrease of GI in cereal products.

Dietary fiber corresponds to the fraction of non-starch polysaccharides, oligosaccharides, analogous carbohydrates, lignin and others, which are resistant to digestion in the small intestine and fermentable in the large intestine; some types of fiber include celluloses, hemicelluloses, arabinoxylans, pectins, oligosaccharides, and polyfructans (Brennan 2008). Recommended intake values for dietary fiber have been established at 38 g/day for men and 25 g/day for women (USDA, 2010).

Table 3 shows that glycemic indices (GI) spaghetti, made with refined and whole wheat, present lower values than white and whole wheat bread (Atkinson et al., 2008), but the use of whole grain does not change the GI in comparison to a similar refined wheat product.

Table 3. Glycemic index (GI) for bread and pasta products[*]

Cereal based foods	GI
Refined wheat bread	75 ± 2
Whole wheat bread	74 ± 2
Spaghetti, refined wheat	49 ± 2
Spaghetti, whole wheat	48 ± 5

[*]Source: Atkinson et al. (2008).

Several studies (Table 4) show the potential of the addition of fibers for developing functional pasta, given that they have demonstrated positive effects on the reduction of GI and, therefore, of the risk of NCDs.

Dietary fiber acts in the gastrointestinal tract by absorbing water, increasing the sensation of satiety and the fecal volume. The consequence is the retardation of digestion and nutrient absorption with decreasing of the GI of the food (Brownlee, 2011; Jenkins, Marchie, Augustin, Ros, & Kendall, 2004; Schulze et al., 2004). Some studies have proved that a fiber-rich diet is effective in the reduction of the risk of type 2 diabetes (McKeown, Meigs, Liu, Wilson, & Jacques, 2002; Schulze et al., 2004), and cardiovascular diseases (Jacobs, Meyer, Kushi, & Folsom, 1998; McKeown et al., 2002; Sahyoun, Jacques, Zhang, Juan, & McKeown, 2006; Streppel, Ocké, Boshuizen, Kok, & Kromhout, 2008). Additionally, a diet rich in fiber can help regulate weight gain (Bazzano et al., 2005; Tucker & Thomas, 2009), as well as reduce obesity (S. Liu et al., 2003; Slavin, 2005).

Bread and pasta have been formulated with the intention of reducing their GI, by strategies such as addition of fiber (Brennan & Tudorica, 2008), and whole grain (Kristensen et al., 2010).

McKeown et al. (2004) in an study with 2,834 patients, related whole grain and low GI foods with a reduced insulin resistance, which could reduce the occurrence of the metabolic syndrome, that according to Grundy (2004), is a condition that includes dyslipidemia, elevated blood pressure, disturbed glucose and insulin metabolism, prothrombic and proinflammatory state.

Table 4. Some characteristics of pastas with fiber addition

Product	Ingredient added	% Substitution	Effects	Reference
Dry spaghetti Durum wheat	Two types of β-glucan (BB and GG)*	2, 4, 6, 8 and 10 g/100 g	Cooking quality similar to the control without fiber. Both reduced the glycemic index, but BB had a higher effect than GG.	Chillo, Ranawana, & Henry (2011)
Dry spaghetti *T. aestivum*	Resistant starch II (RSII), IV (RSIV) and oat bran (OB)	2.5, 5.0, 7.5, and 10.0 g/100 g	RS pastas had similar acceptability to control, but OB pasta had a lower acceptability.	Bustos, Perez, & León (2011)
Dry spaghetti Durum wheat	Wheat germ and bran	Germ: 10, 20, 30, 40, 50, 60 g/100 g Bran: 10, 20, 30 g/100 g	Increased antioxidant activity and cooking loss, and decreased the sensorial quality.	Aravind, Sissons, Egan, & Fellows (2012)
Dry spaghetti Durum wheat *T. aestivum*	Resistant starch (RS) and distilled monoglyceride (DM)	RS: 3.7-25% DM: 0.1-0.7%	RS decreased cooking time of pastas and increased solids loss, while DM increased cooking time.	Vernaza et al. (2012)
Dry spaghetti Durum wheat	Resistant starch RSII and RSIII	RSII: 10, 20, 50 g/100 g RSIII: 10, 20 g/100 g	RS up to 20% had no significant effect on cooking and texture characteristics of pasta, as well as sensory properties. RS decreased *in vitro* starch hydrolysis.	Aravind, Sissons, Fellows, Blazek, & Gilbert (2013)
Dry short pasta Durum wheat	Bran	20, 25, 30, 35 and 40 g/100 g	Bran increased total dietary fiber content, water absorption, and cooking loss of pastas. Up to 20 g/100 g of bran addition, sensory characteristics were similar to pasta with whole durum wheat.	Sobota, Rzedzicki, Zarzycki, & Kuzawinska (2015)
Dry short pasta Durum wheat	High-fiber oat powder	4, 8, 12, 16 and 20 g/100 g	Decreased cooking time, and increased water uptake and swelling index of pasta.	Piwinska, Wyrwisz, Kurek, & Wierzbicka (2015)
Fresh spaghetti Durum wheat	Oat bran, psyllium, β-glucan and inulin	15 g/100 g	Increased the optimal cooking time, swelling index, water absorption and cooking loss of all pastas, and produced dark pastas.	Foschia, Peressini, Sensidoni, Brennan, & Brennan (2015)

*BB: Barley Balance®; GG: Glucagel®.

Analyzing Table 4, the studies done for developing pastas containing fiber indicate modifications in their technological quality, due to the influence of fiber on the weakening of the gluten matrix, altering cooking properties, texture and sensory characteristics (Manthey, 2002), which are more perceived when fibers were used at higher concentrations. However, some alternatives may be used, for taking better advantage of the associated beneficial ingredients, such as format change, passing from long pasta type spaghetti, whose drying process requires a strict control, to short or sheeted pasta, with an easier drying process. In addition, in the case that the pastas present high cooking solids loss, they could be indicated for use in soups.

With respect to pastas healthiness, the use of fibers in foods decreases the caloric value and promotes satiety for longer periods, since the slow digestion of carbohydrates reduces the liberation of high insulin concentrations.

Besides fibers use, the associated or not consumption of phytochemicals in pastas may help reduce the occurrence of NCDs.

2.2 Antioxidants in pasta as healthiness promoters

Table 5 shows some studies done with the purpose of increasing the total phenolic content and antioxidant capacity of pasta.

According to Liu (2007), the most important phytochemicals from vegetable and grain sources include phenolics, carotenoids, vitamin E compounds, lignans, β-glucan, sterols and stanols. They can be grouped as following, with their respective effects on health:

- Common phenolic acids are ferulic, vanillic, caffeic, syringic and *p*-coumaric acid. The first of them, ferulic acid (trans-4-hydroxy-3-methoxycinnamic acid), is predominantly present in the aleurone, pericarp and embryo cells of grains, but less in the starchy endosperm (Shahidi & Liyana-Pathirana 2008). In whole grains, phenolics exist principally in the bound form, followed by soluble-conjugated, and finally as free (Adom & Liu 2002). In the human body, phenolic compounds are thought to reduce the risk of several chronic diseases by reducing oxidative stress (Temple, 2000).
- Carotenoids include lutein, zeaxanthin, β-cryptoxanthin, α-carotene and β-carotene. Carotenoids play a role as provitamins, antioxidants, and pigments. Due to the series of conjugated double bonds in the central part of the molecule, carotenoids have the

ability to react with free radicals, producing less reactive molecules. (Adom & Liu 2002, Adom et al 2005).

- Vitamin E is found in the form of tocopherols and tocotrienols, predominantly present in the germ fraction of grains. In the human body, vitamin E presents antioxidant activity, helps to protect cellular lipids, proteins and DNA, as well as prevent cardiovascular diseases, maintain reproductive function, and other metabolic processes (Brigelius-Flohé & Traber 1999).
- Lignans are composed of dietary phytoestrogen which presents strong antioxidant activity (Tsao, 2008).
- β-glucan is present in cell walls of oat, barley and wheat. It corresponds to a group of polymers of glucose with β-(1-4) and β-(1-3) linkages, with properties of solubility and viscosity. β-glucan has proved to lower blood cholesterol, control blood sugar and enhance the immune system. With similar effects to β-glucan, sterols and stanols are also available from vegetable and grain sources (Liu 2007).

The use of antioxidant compounds presents many perspectives, and new presentation types for consumers may be done. For example, in the case of a high lixiviation of antioxidant compounds into the cooking water, pasta would be recommended for use in soups, or that the cooking water could be reused for cooking another food or making a sauce. New forms of commercialization should be explored, such as industrially pre-cooked and dry pastas, for facilitating domestic use, eliminating the cooking step, with a direct hydration in the food preparation, as lasagna, cannelloni, and the offer of ready-to-eat pastas.

Similar to some works mentioned in Table 5, the use of whole grain wheat flour in pasta sums the benefits of fiber and antioxidants, with functional and economic effects, as will be discussed hereafter.

Table 5. Antioxidant ingredients added to pastas

Product	Ingredient added	% Substitution	Effects	Reference
Fresh fettucine Durum wheat	Oregano and carrot leaf addition	5 and 10 g/100 g	10% of oregano leaves increased total phenolics content and DPPH in cooked pasta. Leaves increased omega-3 fatty acid content with acceptable sensory evaluation.	Boroski et al. (2011)
Dry spaghetti Durum wheat	Raw and toasted chickpea flour	5, 10, 15 and 20 g/100 g	Increased resistant starch and dietary fiber content of pasta. Toasted chickpea pasta had higher values of total phenolics content and antioxidant activity than raw chickpea pasta.	Fares & Menga (2012)
Dry fettucine *T. aestivum*	High-maize starch Low and high methoxyl pectin Elderberry juice concentrate	Fibers: 20 g/100 g Juice: 100 mL/100 g	Pectin and juice caused higher cooking losses than high-maize starch pastas. Pectin and high-maize starch increased total dietary fiber of pastas. Elderberry juice increased the total phenolics content and the total antioxidant activity.	Sun-Waterhouse, Jin, & Waterhouse (2013)
Dry fettucine Durum wheat	Red sorghum flour (RSF) and white sorghum flour (WSF)	20, 30 and 40 g/100 g	Increased the resistant starch content, bound phenolic acids, total phenolic content and antioxidant capacity.	Khan, Yousif, Johnson, & Gamlath (2013)
Dry fettucine *T. aestivum*	Spirulina	5, 10 and 20 g/100 g	Spirulina increased the total phenolics content, antioxidant activity, and cooking loss of pasta, but decreased cooking time. No differences in glycemic index were observed.	Rodríguez De Marco, Steffolani, Martínez, & León (2014)
Fresh fettucine *T. aestivum*	Grape powder	2.5, 5 and 7.5 g/100 g	Grape increased total phenolic, condensed tannins, anthocyanin compounds and antioxidant capacity in the cooked pasta, but reduced the sensory acceptance.	Sant´Anna, Christiano, Marczak, Tessaro, & Thys (2014)
Dry fettucine Durum wheat	Carob flour	1, 2, 3, 4 and 5 g/100 g	Carob flour increased total phenolics content, antioxidant activity, and glycemic index of pastas, without changes in sensory evaluation.	Seczyk, Swieca, & Gawlik-Dziki (2016)
Dry fettucine Durum wheat	Parsley leaves	1, 2, 3 and 4 g/100 g	Parsley leaves increased total phenolics content and antioxidant activity (ABTS and FRAP methods), reduced protein digestibility, and had no effect on starch digestibility.	Seczyk, Swieca, Gawlik-Dziki, Luty, & Czyz (2016)

2.3 Whole wheat pastas: a way for complete use of healthy compounds

Some studies have been done on pastas containing whole wheat flour, but all of them share difficulties due to alterations in texture and cooking properties, caused by fiber from bran (Manthey, 2002). Additionally, whole wheat flour presents a reduced storage stability and shorter shelf-life than refined wheat flour, because of the higher content of lipids, which are more sensitive to oxidation (Doblado-Maldonado, Pike, Sweley, & Rose, 2012). Therefore, the development of whole wheat pasta would present several advantages in terms of functional and economical properties.

Whole wheat possesses higher contents of antioxidants, minerals, vitamins, and fiber than refined wheat. Table 6 shows the differences between whole wheat and refined wheat in their proximate and antioxidants composition, caused by the milling and refining process. Wheat bran and germ contain more antioxidant compounds, such as phenolic, ferulic acid, flavonoids and carotenoids than the endosperm (Adom et al., 2005). During milling, there are other losses in vitamins E and B6, minerals such as magnesium, manganese, zinc, potassium, phosphorous, and dietary fiber contents, principally found in the bran and in the germ (Doblado-Maldonado et al., 2012).

On the other side, the economic benefits of the use of whole wheat flour are related to the whole use of the wheat grain and a consequent decrease in milling losses, which in the traditional milling process are approximately 25%. Whole wheat use would benefit the countries that import wheat for pastas, and are pasta producers (Table 1, for example, Brazil and Iran), due to the fact that a reduced number of them are autosufficient in the production of wheat for pasta *(Triticum durum*).

As whole wheat pastas present different color and texture to conventional pasta, some studies have been done for obtaining technological and functional modifications, such as Marcato et al. (2015), that used yam flour (up to 15%) for modifying whole wheat pasta color and technological properties, obtaining a lighter color in pasta and good antioxidant capacity in terms of DPPH and ABTS. Similarly, Vilar et al. (2015) studied the addition of turmeric flour (up to 9%) in whole wheat pasta, observing that turmeric caused a significant increase in total phenolic contents, DPPH and ABTS capacities of whole wheat pasta, giving also a pleasant yellow color. These studies also aimed to use regional products, in order to give more value to agribusiness, in this form increasing the benefits for non-wheat producers.

Table 6. Chemical composition of whole wheat and refined wheat flour

Nutrients	Unit	Whole wheat flour	Refined wheat flour	Losses during refining (%)
Energy [a]	kcal/100g	340	364	
Proteins [a]	g/100g	13.21	10.33	21.80
Lipids [a]	g/100g	2.50	0.98	60.80
Ash [a]	g/100g	1.58	0.47	70.25
Total carbohydrates, by difference [a]	g/100g	71.97	76.31	c
Total dietary fiber [a]	g/100g	10.7	2.7	74.77
Moisture [a]	g/100g	10.74	11.92	c
Total phenolic compounds [b]	µmol of gallic acid equiv/100 g	662.86	185.50	72.02
Ferulic acid content [b]	µmol/100 g	196.42	18.00	90.84
Flavonoid content [b]	µmol of catechin acid equiv/100 g	200.90	70.00	65.16
Carotenoid content [b]				
Lutein	µg/100 g	74.90	53.80	28.17
Zeaxanthin	µg/100 g	5.65	2.15	62.03
β-cryptoxanthin	µg/100 g	4.88	3.95	19.23
Hydrophilic antioxidant activity [b]	µmol of vitamin C equiv/g	2.48	0.58	76.51
Lipophilic antioxidant activity [b]	nmol of vitamin E equiv/g	594.24	55.00	90.74

[a] Source: USDA Agricultural Research Service (2015)
[b] Adapted from Adom et al. (2005), calculated taking endosperm as 83% of the whole grain, and bran+germ as 17%. For refined wheat flour, values are endosperm average value.
[c] Carbohydrates and moisture values increase with refined flour production, as the endosperm fraction is concentrated.

Due to the fact that whole wheat flour already presents a detrimental effect on gluten quality, and that studies have shown that it is possible to vary the quantity of whole wheat to be added, future perspectives appear in the use of whole wheat flours of cereals, pseudo-cereals, legumes, among others, as will be seen hereafter.

2.4 Pasta with varied ingredients addition

Pasta presents good nutritional quality in terms of carbohydrates and energy, but its protein is deficient in lysine and threonine, two essential aminoacids, cited by Chillo et al. (2008). Therefore, several studies have added protein-containing ingredients to pasta, for supplying these valuables aminoacids, as is the case of legumes, and pseudo-cereals, e.g. broad bean, hard-to-cook bean hydrolysate, soy flour, amaranth flour, among others.

Table 7 presents some of the varied ingredients that have been proposed and studied for modifying pasta nutritional and technological characteristics.

3. General considerations

- The production of functional pasta depends greatly from the effects that the ingredients have on chemical, technological and sensorial properties, given that the pasta structure relies completely on the starch-gluten interaction, and new ingredients addition could alter this balance.
- Sensory evaluation must accompany functional pastas development, in order to test their consumer acceptance, which ultimately decides their market success.
- Few studies with whole wheat pasta were found in the present review; however, the use of whole wheat represents an advantage given the contribution in fiber and antioxidant compounds it possesses. The addition of tubers and roots flours, due to their high fiber and antioxidants contents, would represent a viable alternative for modifying whole wheat behavior and the outcome in functional and technological characteristics of pasta.
- Finally, studies for establishing presentation format, drying process, cooking process (pre-cooked, ready-to-eat, conventional) are determinant for new ingredients inclusion aiming their whole use with health benefits.

Table 7. Ingredients added to pastas

Product	Ingredient added	% Substitution	Effects	Reference
Dry spaghetti *T. aestivum*	Broad bean flour	10, 20 and 30 g/100 g	Increased protein, dietary fiber also increased and cooking loss, and decreased the water absorption of pastas.	Giménez et al. (2012)
Dry fettucine Durum wheat	Mushroom powder, Bengal gram flour and defatted soy flour	Mushroom powder: 6, 8, 10 and 12 g/100 g Bengal gram flour: 6, 9, 12, 15, 18 and 21 g/100 g Defatted soy flour: 6, 9, 12 and 15 g/100 g	Increased the water absorption and the swelling of the cooked pasta, modified the cooking time.	Kaur, Sharma, Nagi, & Ranote (2013)
Dry spaghetti Durum wheat	Buckwheat flour and bran	10, 15, 20, and 30 g/100 g	Increased the total phenolic contents, the cooking loss and carbohydrate digestibility, but decreased the swelling index.	Biney & Beta (2014)
Dry fettucine Durum wheat	Raw and popped amaranth flour	25, 50, 75 and 100 g/100 g	Increased protein, fat, ash and cooking loss, but decreased the weight gain in cooked pastas.	Islas-Rubio, Calderón de la Barca, Cabrera-Chávez, Cota-Gastélum, & Beta (2014)
Dry spaghetti Durum wheat	Hard-to-cook bean hydrolysate	5 and 10 g/100 g	Pastas presented both ACE (angiotensin I-converting enzyme) inhibitor and antioxidant activity.	Segura-Campos, García-Rodríguez, Ruiz-Ruiz, Chel-Guerrero, & Betancur-Ancona (2014)
Dry penna rigata Durum wheat	Barley flour enriched with β-glucan and *Bacillus coagulans*	Barley flour:18 g/100 g Freeze dried culture: 1 g/100 g	Increased total dietary fiber and preserved the viability of the probiotic bacteria.	Fares et al. (2015)
Dry ziti-cut pasta Durum wheat	Finger millet flour, pearl millet flour and carrot pomace powder	Finger millet flour, pearl millet flour: 10, 20, 30, 40, 50 g/100 g carrot pomace powder: 2, 4, 6, 8, 10 g/100 g	Increased the cooking loss, weight gain and decreased firmness and luminosity (L*).	Gull, Prasad, & Kumar (2015)
Dry spaghetti Whole durum wheat	Tomato peels-based flour	10, 15, 20 and 25 g/100 g	Increased sensory score, starch digestibility, lycopene and β-carotene contents.	Padalino et al. (2015)

4. Conclusion

It is possible to make pastas healthier with the addition of functional ingredients with beneficial health effects, considering also the selection of the most suitable formats and cooking process of pastas to be offered to the consumer. Further researches on pastas containing fiber, antioxidant compounds and other ingredients, as well as whole wheat pasta, may bring new insights for reducing the risk of several NCDs.

5. Acknowledgements

The authors are thankful to *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq) for the scholarship for Adriana Lucia Wahanik, and *Fundação de apoio ao ensino, pesquisa e extensão (FAEPEX)* from UNICAMP.

6. References

Adom, K. K., & Liu, R. H. (2002). Antioxidant activity of grains. *Journal of Agricultural and Food Chemistry*, *50*(21), 6182–7. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/23944941

Adom, K. K., Sorrells, M. E., & Liu, R. H. (2005). Phytochemicals and antioxidant activity of milled fractions of different wheat varieties. *Journal of Agricultural and Food Chemistry*, *53*(6), 2297–306. doi:10.1021/jf048456d

Aravind, N., Sissons, M., Egan, N., & Fellows, C. (2012). Effect of insoluble dietary fibre addition on technological, sensory, and structural properties of durum wheat spaghetti. *Food Chemistry*, *130*(2), 299–309. doi:10.1016/j.foodchem.2011.07.042

Aravind, N., Sissons, M., Fellows, C. M., Blazek, J., & Gilbert, E. P. (2013). Optimisation of resistant starch II and III levels in durum wheat pasta to reduce in vitro digestibility while maintaining processing and sensory characteristics. *Food Chemistry*, *136*(2), 1100–9. doi:10.1016/j.foodchem.2012.08.035

Atkinson, F. S., Foster-Powell, K., & Brand-Miller, J. C. (2008). International tables of glycemic index and glycemic load values: 2008. *Diabetes Care*, *31*(12), 2281–3. doi:10.2337/dc08-1239

Bazzano, L. a, Song, Y., Bubes, V., Good, C. K., Manson, J. E., & Liu, S. (2005). Dietary intake of whole and refined grain breakfast cereals and weight gain in men. *Obesity Research*, *13*(11), 1952–60. doi:10.1038/oby.2005.240

Beaglehole, R., Bonita, R., Horton, R., Adams, C., Alleyne, G., Asaria, P., Watt, J. (2011). Priority actions for the non-communicable disease crisis. *Lancet*, *377*, 1438–47. doi:10.1016/S0140-6736(11)60393-0

Biney, K., & Beta, T. (2014). Phenolic profile and carbohydrate digestibility of durum spaghetti enriched with buckwheat flour and bran. *LWT - Food Science and Technology*, *57*(2), 569–579. doi:10.1016/j.lwt.2014.02.033

Boroski, M., Aguiar, A., Boeing, J., Rotta, E., Wibby, C., Bonafé, E., Souza, N., Visentainer, J. (2011). Enhancement of pasta antioxidant activity with oregano and carrot leaf. *Food Chemistry*, *125*(2), 696–700. doi:10.1016/j.foodchem.2010.09.068

Brennan, C. S. (2008). High-fibre pasta products. In B. R. Hamaker (Ed.), *Technology of functional cereal products*. Cambridge: Woodhead Publishing Limited.

Brennan, C., & Tudorica, C. (2008). Evaluation of potential mechanisms by which dietary fibre additions reduce the predicted glycaemic index of fresh pastas. *International Journal of Food Science and Technology*, *43*, 2151–2162. doi:10.1111/j.1365-2621.2008.01831.x

Brigelius-Flohé, R., & Traber, M. G. (1999). Vitamin E: function and metabolism. *The FASEB Journal*, 1145–1155.

Brownlee, I. a. (2011). The physiological roles of dietary fibre. *Food Hydrocolloids*, *25*(2), 238–250. doi:10.1016/j.foodhyd.2009.11.013

Bustos, M. C., Perez, G. T., & Leon, A. E. (2015). Structure and quality of pasta enriched with functional ingredients. *RSC Advances*, *5*, 30780–30792. doi:10.1039/C4RA11857J

Bustos, M. C., Perez, G. T., & León, A. E. (2011). Sensory and nutritional attributes of fibre-enriched pasta. *LWT - Food Science and Technology*, *44*(6), 1429–1434. doi:10.1016/j.lwt.2011.02.002

Chillo, S., Laverse, J., Falcone, P. M., Protopapa, A., & Nobile, M. A. Del. (2008). Influence of the addition of buckwheat flour and durum wheat bran on spaghetti quality, *47*, 144–152. doi:10.1016/j.jcs.2007.03.004

Chillo, S., Ranawana, D. V, & Henry, C. J. K. (2011). LWT - Food Science and Technology Effect of two barley b -glucan concentrates on in vitro glycaemic impact and cooking quality of spaghetti. *LWT - Food Science and Technology*, *44*(4), 940–948. doi:10.1016/j.lwt.2010.11.022

Doblado-Maldonado, A. F., Pike, O. A., Sweley, J. C., & Rose, D. J. (2012). Key issues and challenges in whole wheat flour milling and storage. *Journal of Cereal Science*, *56*(2), 119–126. doi:10.1016/j.jcs.2012.02.015

Fares, C., & Menga, V. (2012). Effects of toasting on the carbohydrate profile and antioxidant properties of chickpea (Cicer arietinum L .) flour added to durum wheat pasta. *Food Chemistry*, *131*, 1140–1148. doi:10.1016/j.foodchem.2011.09.080

Fares, C., Menga, V., Martina, A., Pellegrini, N., Scazzina, F., & Torriani, S. (2015). Nutritional pro fi le and cooking quality of a new functional pasta naturally enriched in phenolic acids , added with b -glucan and Bacillus. *Journal of Cereal Science*, *65*, 260–266. doi:10.1016/j.jcs.2015.07.017

Foschia, M., Peressini, D., Sensidoni, A., Brennan, M. A., & Brennan, C. S. (2015). How combinations of dietary fibres can affect physicochemical characteristics of pasta. *LWT - Food Science and Technology*, *61*(1), 41–46. doi:10.1016/j.lwt.2014.11.010

Fuad, T., & Prabhasankar, P. (2010). Role of ingredients in pasta product quality : A review on recent developments. *Critical Reviews in Food Science and Nutrition*, *50*, 787–798. doi:10.1080/10408390903001693

Giménez, M. A., Drago, S. R., Greef, D. De, Gonzalez, R. J., Lobo, M. O., & Samman, N. C. (2012). Rheological , functional and nutritional properties of wheat / broad bean (Vicia faba) flour blends for pasta formulation, *134*, 200–206. doi:10.1016/j.foodchem.2012.02.093

Grundy, S. M. (2004). Obesity, metabolic syndrome, and cardiovascular disease. *The Journal of Clinical Endocrinology and Metabolism*, *89*(6), 2595–600. doi:10.1210/jc.2004-0372

Gull, A., Prasad, K., & Kumar, P. (2015). Effect of millet flours and carrot pomace on cooking qualities, color and texture of developed pasta. *LWT - Food Science and Technology*, *63*(1), 470–474. doi:10.1016/j.lwt.2015.03.008

Habib, S. H., & Saha, S. (2010). Burden of non-communicable disease: Global overview. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *4*(1), 41–47. doi:10.1016/j.dsx.2008.04.005

IPO. (2013). *The world pasta industry status report 2013*. Retrieved from http://www.internationalpasta.org/index.aspx?Lang=2

Islas-Rubio, A. R., Calderón de la Barca, A. M., Cabrera-Chávez, F., Cota-Gastélum, A. G., & Beta, T. (2014). Effect of semolina replacement with a raw:popped amaranth flour blend on cooking quality and texture of pasta. *LWT - Food Science and Technology*, *57*(1), 217–222. doi:10.1016/j.lwt.2014.01.014

Jacobs, D. R., Meyer, K. A., Kushi, L. H., & Folsom, A. R. (1998). Whole-grain intake may reduce the risk of ischemic heart disease death in postmenopausal women: the Iowa Women's Health Study. *The American Journal of Clinical Nutrition*, *68*(2), 248–57. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9701180

Jenkins, D. J. A., Marchie, A., Augustin, L. S. A., Ros, E., & Kendall, C. W. C. (2004). Viscous dietary fibre and metabolic effects. *Clinical Nutrition Supplements*, *1*(2), 39–49. doi:10.1016/j.clnu.2004.09.007

Jenkins, D. J. A., Wolever, T. M. S., Taylor, R. H., Barker, H., Fielden, H., Baldwin, J. M., … Goff, D. V. (1981). Glycemic index of foods: a physiological basis for carbohydrate exchange. *The American Journal of Clinical Nutrition*, 362–366.

Kaur, G., Sharma, S., Nagi, H. P. S., & Ranote, P. S. (2013). Enrichment of pasta with different plant proteins. *Journal of Food Science and Technology*, *50*(October), 1000–1005. doi:10.1007/s13197-011-0404-2

Khan, I., Yousif, A., Johnson, S. K., & Gamlath, S. (2013). Effect of sorghum flour addition on resistant starch content, phenolic profile and antioxidant capacity of durum wheat pasta. *Food Research International*, *54*(1), 578–586. doi:10.1016/j.foodres.2013.07.059

Kill, R. C., & Turnbull, K. (Eds.). (2001). *Pasta and Semolina Technology*. Oxford: Blackwell Science Ltd.

Krishnan, M., & Prabhasankar, P. (2012). Health based pasta : Redefining the concept of the next generation convenience food. *Critical Reviews in Food Science and Nutrition*, *52*, 9–20. doi:10.1080/10408398.2010.486909

Kristensen, M., Jensen, M. G., Riboldi, G., Petronio, M., Bügel, S., Toubro, S., Astrup, A. (2010). Wholegrain vs. refined wheat bread and pasta. Effect on postprandial glycemia , appetite , and subsequent ad libitum energy intake in young healthy adults. *Appetite*, *54*, 163–169. doi:10.1016/j.appet.2009.10.003

Li, M., Zhu, K.-X., Guo, X.-N., Brijs, K., & Zhou, H.-M. (2014). Natural additives in wheat-based pasta and noodle products : Opportunities for enhanced nutritional and functional properties. *Comprehensive Reviews in Food Science and Food Safety*, *13*, 347–357. doi:10.1111/1541-4337.12066

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

Liu, S., Willett, W. C., Manson, J. E., Hu, F. B., Rosner, B., & Colditz, G. (2003). Relation between changes in intakes of dietary fiber and grain products and changes in weight and development of obesity among middle-aged women. *The American Journal of Clinical Nutrition*, *78*(5), 920–7. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14594777

Manthey, F. A. (2002). Processing and quality of whole-wheat pasta. In L. Marquart, J. L. Slavin, & R. G. Fulcher (Eds.), *Whole-grain foods in health and disease*. St. Paul: AACC.

Marcato, A. R., Felisberto, M. H. F., Wahanik, A. L., Pastore, G. M., Neri-Numa, I. A., & Clerici, M. T. P. S. (2015). Yam flour (Dioscorea alata L.) in fresh pasta of whole grain wheat flour. In *XXIII Congresso da Iniciação Cientifica da Unicamp*. Campinas. doi:http://dx.doi.org/10.19146/pibic-2015-37036

McKeown, N. M., Meigs, J. B., Liu, S., Saltzman, E., Wilson, P. W. F. F., & Jacques, P. F. (2004). Carbohydrate Nutrition, Insulin Resistance, and the Prevalence of the Metabolic Syndrome in the Framingham Offspring Cohort. *Diabetes Care*, *27*(2), 538–46. doi:10.2337/diacare.27.2.538

McKeown, N. M., Meigs, J. B., Liu, S., Wilson, P. W. F., & Jacques, P. F. (2002). Whole-grain intake is favorably associated with metabolic risk factors for type 2 diabetes and cardiovascular disease in the Framingham Offspring Study. *The American Journal of Clinical Nutrition*, *76*(2), 390–8. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12145012

Menrad, K. (2003). Market and marketing of functional food in Europe. *Journal of Food Engineering*, *56*(2-3), 181–188. doi:10.1016/S0260-8774(02)00247-9

Padalino, L., Conte, A., Lecce, A., Likyova, D., Sicari, V., Tm, P., … Ma, D. N. (2015). Durum wheat whole-meal spaghetti with tomato peels : how by-product particles size can affect final quality of pasta. *J. Food Process Technology*, *6*(10). doi:10.4172/2157-7110.1000500

Pataco, I., Mourinho, M., Oliveira, K., Santos, C., Pelica, J., Pais, I., … Pessoa, M. (2015). Durum Wheat (Triticum durum) biofortification in iron and definition of quality parameters for the industrial production of pasta – A review. *Emir. Journal of Food Agriculture*, *27*, 242–249.

Patil, S. K. (2008). Improving the use of dietary fiber and other functional ingredients to lower the glycemic index of cereal products. In B. R. Hamaker (Ed.), *Technology of functional cereal products*. Cambridge: Woodhead Publishing Limited.

Piwinska, M., Wyrwisz, J., Kurek, M., & Wierzbicka, A. (2015). Hydration and physical properties of vacuum-dried durum wheat semolina pasta with high- fiber oat powder. *LWT - Food Science and Technology*, *63*, 647–653. doi:10.1016/j.lwt.2015.03.022

Rodríguez De Marco, E., Steffolani, M. E., Martínez, C. S., & León, A. E. (2014). Effects of spirulina biomass on the technological and nutritional quality of bread wheat pasta. *LWT - Food Science and Technology*, *58*, 102–108. doi:10.1016/j.lwt.2014.02.054

Sahyoun, N. R., Jacques, P. F., Zhang, X. L., Juan, W., & McKeown, N. M. (2006). Whole-grain intake is inversely associated with the metabolic syndrome and mortality in older adults. *The American Journal of Clinical Nutrition*, *83*(1), 124–31. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16400060

Sant´Anna, V., Christiano, F. D. P., Marczak, L. D. F., Tessaro, I. C., & Thys, R. C. S. (2014). The effect of the incorporation of grape marc powder in fettuccini pasta properties. *LWT - Food Science and Technology*, *58*, 497–501. doi:10.1016/j.lwt.2014.04.008

Schulze, M. B., Liu, S., Rimm, E. B., Manson, J. E., Willett, W. C., & Hu, F. B. (2004). Glycemic index, glycemic load, and dietary fiber intake and incidence of type 2 diabetes in younger and middle-aged women. *The American Journal of Clinical Nutrition*, *80*(2), 348–56. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15277155

Seczyk, L., Swieca, M., & Gawlik-Dziki, U. (2016). Effect of carob (Ceratonia siliqua L.) flour on the antioxidant potential, nutritional quality, and sensory characteristics of fortified durum wheat pasta. *Food Chemistry*, *194*, 637–642. doi:10.1016/j.foodchem.2015.08.086

Seczyk, L., Swieca, M., Gawlik-Dziki, U., Luty, M., & Czyz, J. (2016). Effect of fortification with parsley (Petroselinum crispum Mill.) leaves on the nutraceutical and nutritional quality of wheat pasta. *Food Chemistry*, *190*, 419–428. doi:10.1016/j.foodchem.2015.05.110

Segura-Campos, M. R., García-Rodríguez, K., Ruiz-Ruiz, J. C., Chel-Guerrero, L., & Betancur-Ancona, D. (2014). In vitro bioactivity , nutritional and sensory properties of semolina pasta added with hard-to-cook bean (Phaseolus vulgaris L.) protein hydrolysate. *Journal of Functional Foods*, *8C*, 1–8. doi:10.1016/j.jff.2014.02.016

Shahidi, F., & Liyana-Pathirana, C. (2008). Antioxidant properties of wheat grains and its fractions. In L. Yu (Ed.), *Wheat antioxidants*. Hoboken, New Jersey: John Wiley & Sons, Inc.

Slavin, J. (2005). Dietary fiber and body weight. *Nutrition*, *21*(3), 411–8. doi:10.1016/j.nut.2004.08.018

Sobota, A., Rzedzicki, Z., Zarzycki, P., & Kuzawinska, E. (2015). Application of common wheat bran for the industrial production of high-fibre pasta. *International Journal of Food Science and Technology*, *50*, 111–119. doi:10.1111/ijfs.12641

Streppel, M. T., Ocké, M. C., Boshuizen, H. C., Kok, F. J., & Kromhout, D. (2008). Dietary fiber intake in relation to coronary heart disease and all-cause mortality over 40 y: the Zutphen Study. *The American Journal of Clinical Nutrition*, *88*(4), 1119–25. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18842802

Sun-Waterhouse, D., Jin, D., & Waterhouse, G. I. N. (2013). Effect of adding elderberry juice concentrate on the quality attributes, polyphenol contents and antioxidant activity of three fibre-enriched pastas. *Food Research International*, *54*(1), 781–789. doi:10.1016/j.foodres.2013.08.035

Temple, N. (2000). Antioxidants and disease: more questions than answers. *Nutrition Research*, *20*(3), 449–459.

Tsao, R. (2008). Carotenoid, Tocopherol, Lignan, Flavonoid, and Phytosterol compositions of wheat grain and its fractions. In L. Yu (Ed.), *Wheat antioxidants*. Hoboken, New Jersey: John Wiley & Sons, Inc.

Tucker, L. a, & Thomas, K. S. (2009). Increasing total fiber intake reduces risk of weight and fat gains in women. *The Journal of Nutrition*, *139*(3), 576–81. doi:10.3945/jn.108.096685

USDA. (2010). Dietary Reference Intakes: Recommended Intakes for Individuals. Washington: Food and Nutrition Board USDA. Retrieved from http://fnic.nal.usda.gov/dietary-guidance/dietary-reference-intakes/dri-tables

USDA Agricultural Research Service, N. D. L. (2015). *USDA National Nutrient Database for Standard Reference, Release 28*. Retrieved from http://www.ars.usda.gov/nea/bhnrc/ndl

Vernaza, M. G., Biasutti, E., Schmiele, M., Jaekel, L. Z., Bannwart, A., & Chang, Y. K. (2012). Effect of supplementation of wheat flour with resistant starch and monoglycerides in pasta dried at high temperatures. *International Journal of Food Science & Technology*, *47*(6), 1302–1312. doi:10.1111/j.1365-2621.2012.02974.x

Vilar, I., Wahanik, A. L., Felisberto, M. H. F., Pastore, G. M., Neri-Numa, I. A., & Clerici, M. T. P. S. (2015). Use of Turmeric (Cúrcuma longa) flour as a natural ingredient in fresh pasta of whole grain wheat flour. In *XXIII Congresso da Iniciação Cientifica da Unicamp*. Campinas. doi:http://dx.doi.org/10.19146/pibic-2015-37388

Wagner, K.-H., & Brath, H. (2012). A global view on the development of non communicable diseases. *Preventive Medicine*, *54 Suppl*, S38–41. doi:10.1016/j.ypmed.2011.11.012

WHO. (2014a). Non communicable diseases. Retrieved from http://www.who.int/mediacentre/factsheets/fs355/en/

WHO. (2014b). Obesity, World Health Organization. Retrieved from http://www.who.int/topics/obesity/en/

Wiseman, G. (2001). Durum wheat. In R. C. Kill & K. Turnbull (Eds.), *Pasta and semolina technology*. Oxford: Blackwell Science Ltd.

SECOND ARTICLE: TECHNOLOGICAL AND ANTIOXIDANT CHARACTERISTICS OF WHOLE WHEAT PASTA WITH NATURAL COLORED CONCENTRATES

Adriana Lucia Wahanik, Iramaia Angélica Neri-Numa, Glaucia Maria Pastore, Yoon Kil Chang, Maria Teresa Pedrosa Silva Clerici

Article submitted to "*Food Science and Technology International*"

TECHNOLOGICAL AND ANTIOXIDANT CHARACTERISTICS OF WHOLE WHEAT PASTA WITH NATURAL COLORED CONCENTRATES

Adriana Lucia Wahanik[a], Iramaia Angélica Neri-Numa[b], Glaucia Maria Pastore[b], Yoon Kil Chang[a], Maria Teresa Pedrosa Silva Clerici[a]*

[a]*Food Technology Department, School of Food Engineering, University of Campinas (UNICAMP), 13083-862, Campinas, São Paulo, Brazil*

[b]*Food Science Department, School of Food Engineering, University of Campinas (UNICAMP), 13083-862, Campinas, São Paulo, Brazil*

*Corresponding author. Tel.: +55 19 3521 4000. E-mail address: mclerici@unicamp.br

Abstract

Whole wheat pasta is rich in fiber and antioxidants, but presents dark color and altered cooking characteristics. This study aimed to evaluate the effects of yellow (YNC) and pink (PNC) natural concentrates in whole wheat pasta, on its fiber content, and technological, and antioxidant properties. Control pasta (CP) was prepared (70:30 w:w whole grain wheat (WGF): refined wheat flour (RWF)). YNC and PNC were applied (1 to 2 g/100 g) in pastas containing 60 to 70 g/100 g of WGF, following a 2^2 experimental design, with three central points. YNC and PNC effectively modified whole wheat pastas color, without altering its technological characteristics. Yellow pasta (YP1, 60:40 WGF:RWF w:w, 1 g YNC/100 g) and pink pasta (PP9, 70:30 WGF:RWF w:w, 1 g PNC/100 g) presented similar texture, weight gain and cooking loss to CP, and they were selected. The three pastas had high fiber content (6.64 to 7.31 g/100 g), and PNC caused a significant increase in total phenolics content in raw and cooked whole wheat pasta. The natural colored concentrates are an alternative for modifying the color of whole wheat pasta while adding functional value to it.

Keywords: whole wheat, fiber, color, clean-label, healthiness

Abbreviations:

w: weight

v: volume

db: dry basis

NCDs: non-communicable diseases

WGF: whole grain wheat flour

RWF: refined wheat flour

YNC: yellow natural concentrate

PNC: pink natural concentrate

TPC: total phenolics content

DPPH: 2,2-diphenyl-1-picrylhydrazyl radical for antioxidant capacity analysis

ABTS: 2,2-azinobis (3-ethyl-benzothiazoline-6-sulfonic acid) for antioxidant capacity analysis

ANOVA: analysis of variance

1. Introduction

Healthy diets, belonging to the food market trend “health and well-being”, include more natural, *clean-label*, and functional foods, which have a growing demand due to the increase in non-communicable diseases (NCDs). To this trend belongs the development of functional foods containing antioxidants, whole grains, vegetables, with fewer additives, and minimally processed foods (FIESP & ITAL, 2010). Furthermore, research has also focused on the amounts of additives present in foods, especially the ones destined for children, such as the need of reduction in artificial colorants that may cause allergic reactions and attention disorders (Stevens et al., 2014).

According to Slavin (2003), whole grains present four main properties with health benefits: “large-bowel effects, glucose and insulin changes, antioxidant effect, and presence of other bioactive compounds”. Previous studies in this topic and dietary guidelines all over the world have strongly recommended the consumption of whole grains and dietary fiber, indicating that it would be beneficial to substitute half of the grains consumed by whole grains (at least 3 servings per day, where 1 serving corresponds to 16 g) (Jonnalagadda et al., 2011). Taking this in mind and considering that pasta is widely consumed all over the world, several efforts have been made for whole wheat pasta development, but it presents dark color and poor cooking properties (Manthey & Schorno, 2002). Even though some natural ingredients have already been used in refined wheat pasta, such as spinach, tomato, and eggs, with market success, their use sometimes presents limitations due to the required concentration and microbiological controls (Kill, 2001). However, and to the best of our knowledge, this has not been developed yet for whole wheat pasta, thus representing an advantage for the whole use of agricultural products.

The aims of our work were the use of commercially available natural colored concentrates in whole wheat flour and the evaluation of their effect on technological properties and antioxidant capacity, for obtaining whole wheat colored pastas with health benefits.

2. Material and methods

2.1 Material

Whole grain wheat flour (WGF) and refined wheat flour (RWF) (*Triticum aestivum*) were bought from Moinho Anaconda (São Paulo, Brazil), while yellow (YNC) and pink (PNC) natural concentrates were kindly donated by GNT Brasil (São Paulo, Brazil). These concentrates are extracted by physical means and with no use of chemical additives, where YNC contains safflower, and PNC is a mixture of cherry, purple sweet potato, apple, and radish. Chemical reagents for measurement of antioxidant capacity were 2,2-azinobis (3-ethyl-benzothiazoline-6-sulfonic acid) (ABTS), gallic acid, 2,2-diphenyl-1-picrylhydrazyl radical (DPPH), and 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox solution), purchased from Sigma-Aldrich, USA. Folin-Ciocalteau phenol reagent was obtained from Dinâmica (Diadema, Brazil), and methanol and ethanol were purchased from Synth (Diadema, Brazil).

2.2 Chemical and technological analysis of raw materials

Proximate analysis of WGF and RWF were moisture (method 44-15.02), protein (method 46-13.01) (factor 5.7), ether extract (method 30-25.01), dietary fiber (method 32-07.01), and ash content (method 08-01.01) (AACC International methods, 2010). Digestible carbohydrates were calculated by difference [= 100 - (moisture + protein + ether ext. + ashes + dietary fiber)]. WGF and RWF were also analyzed for their rheological parameters by farinograph (method 54-21.01) and extensigraph analysis (method 54-10.01). A colorimeter Miniscan XE 3500 (Hunterlab, Reston, VI, USA) (daylight illuminant D65 and 10°) was used for measuring raw materials color (L* (lightness), a*(redness) and b*(yellowness)).

2.3 Colored whole pastas processing and evaluation

2.3.1 Control pasta: natural color

Control formulation (CP) was elaborated with WGF and RWF in the proportion of 70:30 w:w, this proportion being determined by previous tests. Flours were mixed with water (44 g/100 g flour mixture) (determined experimentally) for 15 min in a Pastaia II (capacity: 2 kg) (Italvisa, Tatuí, Brazil), and left to rest for 5 min, before extrusion of spaghetti strands (diameter: 1.8 mm). Fresh pasta was hung in a drying rack for 30 min in a ventilated and cooled room, packed in low density polyethylene (LDPE) bags, white pigmented with 1.5% titanium dioxide (Plastunion Indústria de Plásticos Ltda., Caieiras, Brazil), closed using a packing machine (200B, Selovac, São Paulo, Brazil), and refrigerated (4°C) for 24 hours before technological analysis.

2.3.2 Yellow and pink fresh whole wheat pastas

YP and PP were formulated following a linear experimental design with axial points (-1, +1), and three replicates at the central point (0, 0) (Table 1). Yellow pasta (YP) had independent variables WGF:RWF (X1) (which corresponds to the proportion between whole grain and refined wheat flour) and YNC (X2). Pink pasta (PP) had variables WGF:RWF (Y1) and PNC (Y2). Dependent variables were technological properties: raw and cooked color, cooked texture (cutting force), cooking loss, and weight gain. Pastas were elaborated as indicated in item 2.3.1.

2.3.3 Measurement of pasta chemical and technological properties

Proximate composition of produced pasta followed the methods indicated in item 2.2. Technological properties included cooking test (optimal cooking time (OCT), weight gain, and solids loss) (method 66-50.01, AACC International, 2010), as well as color of raw and cooked pasta (measured as in item 2.2). Color difference, ΔE^*_{ab}, was calculated as $\Delta E^*_{ab} = [\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}]^{1/2}$, where each delta corresponds to the difference in the color parameter between two samples. Texture of cooked pasta was measured with a TA.XT2 Texture Analyzer (Stable Micro Systems, Surrey, England), with a Light Knife Blade (A/LKB) probe (method 66-50.01, AACC International, 2010).

Response Surface Methodology (RSM) for YP and PP was used for determination of regression coefficients, with minimal determination coefficient (R^2) of 0.80 (Neto et al., 2010), followed by analysis of variance (ANOVA, $p \leq 0.05$), with the objective of observing the ingredients effects on pastas quality.

2.4 Selection of colored whole wheat pastas

For determining the pastas with similar characteristics of weight gain, solids loss and pasta cutting force to CP, a Principal Components Analysis (PCA) was done. Data from PCA was plotted in a biplot, where formulations located near CP were selected for evaluation of total phenolics content (TPC) and antioxidant capacity.

2.5 Total phenolic content (TPC) and antioxidant capacity

2.5.1 Extraction and determination of total phenolic contents of whole wheat pasta

Bioactive compounds in pasta were extracted by lyophilizing raw and cooked pasta (Liotop LP820, Liobras, São Carlos, Brazil), grinding and dissolving in methanol in 0.5 mg/mL concentration, then centrifuging at 4900 rpm during 5 min (Baby I 206-BL, Fanem, São Paulo, Brazil). The Folin-Ciocalteau method (Roesler et al., 2007) was followed for determination of total phenolics content (TPC). Briefly, a 200 µL aliquot of pasta extract was mixed with 1000 µL of 10-fold diluted Folin-Ciocalteau reagent and 800 µL of 7.5% sodium carbonate solution. After 5 min reaction at 50 °C, absorbance at 760 nm was read in a spectrophotometer (DU-640™, Beckman-Coulter-Brea, CA, USA). Gallic acid (0.3125 to 50 µg/mL) was used as standard, and the results are expressed as micrograms of gallic acid equivalents (µg GAE/g) in dry basis.

2.5.2 DPPH• assay of whole wheat pasta

DPPH free radical scavenging activity analysis, adapted by Brand-Williams, Cuvelier, & Berset (1995), was done using a standard curve with Trolox (25 to 200 µM). An aliquot of 100 µL pasta extract (prepared in item 2.5) and 100 µl of methanol were mixed with 1000 µL of DPPH solution (0.004% w/v), and left for 30 min reaction in a dark place. The absorbance of the remaining DPPH was measured at 517 nm against a blank. Results are indicated as milligrams of Trolox Equivalent (TE)/g in dry basis.

2.5.3 ABTS scavenging capacity of whole wheat pasta

The radical cation ABTS scavenging capacity of whole wheat pastas was measured using the method described by Re et al. (1999). Briefly, an aliquot of 25 µL pasta extract (prepared as in 2.5) and 175 µl of ethanol were mixed with 1000 µL of diluted ABTS solution (prepared by reacting ABTS stock solution (7 mM) with potassium persulfate (2.45 mM)). Absorbance was read after 6 min at 734 nm against a blank. Trolox was used as standard curve (3.125 to 125 µM) in ethanol. Results are expressed in mg Trolox Equivalent (TE)/g in dry basis.

TPC and antioxidant capacity of selected pastas were evaluated by ANOVA and Tukey´s multiple comparison test ($p \leq 0.05$).

2.8 Statistical analysis

All statistical analyses were done using the software Statistica 7.0 (StatSoft, Tulsa, USA), excepting PCA, done on SAS software version 9.02 (SAS Institute, North Carolina, USA). All the analyses were performed in triplicate, except for texture cutting force of pastas that was done in quintuplicate.

3. Results and discussion

3.1 Chemical and technological analysis of raw materials

Proximate analysis of raw materials indicated that WGF and RWF presented 9.97 and 10.90 g of moisture/100 g of sample, respectively.

When analyzed in 100 g of dry sample, WGF and RWF presented 13.32 ± 0.52 and 12.68 ± 0.84 g of protein, 1.96 ± 0.16 and 1.42 ± 0.17 g of fat, 1.61 ± 0.02 and 0.68 ± 0.02 g of ash, 10.38 ± 1.31 and 2.89 ± 0.17 g of fiber, and 72.73 and 82.33g of carbohydrates, respectively.

Farinographic analysis indicated a higher water absorption by WGF than RWF (65.3 and 58.2%, respectively), while the stability of RWF was superior to WGF (23.1 ± 0.8 and 15.5 ± 0.9 minutes, respectively). Extensigraph analysis at 45 min showed a lower resistance to extension for WGF (434 ± 28 BU) than for RWF (525 ± 35 BU), as well as a lower extensibility for WGF (105 ± 7.5 cm) than RWF (125 ± 7 cm). These results indicate that RWF is a strong flour, given its high stability to mixture, while it presents a medium extensibility and resistance to extension, being appropriate for pasta production.

3.2 Measurement of pasta technological properties

Instrumental color of raw CP was: L*= 46.25 ± 0.17, a*= 11.37 ± 0.36 and b*= 23.43 ± 0.73; after cooking, CP presented a higher luminosity, lower redness and yellowness (L*= 49.79 ± 0.48, a*= 7.20 ± 0.10, b*= 14.57 ± 0.12). An optimal cooking time (OCT) of 270 s was determined, and used for the cooking test, with resulting weight gain of 92.78 ± 5.78 g/100 g, solids loss of 3.95 ± 0.16 g/100 g, and cutting force of 1.52 ± 0.11 N.

Table 1 shows the technological properties for YP and PP, which were used for the Response Surface Methodology (RSM) analysis. Table 2 and Figure 1 indicate the mathematical models and response surfaces for YP. The increase in the concentration of YNC (x_2) increased the redness (a*) of raw YP, but it did not affect any other of the measured technological properties. After pasta cooking, the independent variables had no significant effects on technological properties of YP.

Table 2 and Figure 2 show that for PP, an increase in PNC (y_2) increased the redness (a*) of raw pasta (Fig. 2b), and decreased the lightness (L*) and yellowness (b*) of both raw and cooked pasta (Fig. 2a, 2c, 2d, 2f). Fig. 2e shows that the redness (a*) of cooked PP increased with PNC increase, and simultaneously, it decreased due to the interaction between WGF:RWF and PNC (y_1*y_2); the latter effect could be related to the brownish color of WGF. Moreover, the technological properties of cutting force, weight gain, or cooking losses were not influenced by the variation in flours and colored concentrates, neither in the raw or cooked form.

Table 1. Technological properties of yellow and pink whole wheat pastas

					Raw pasta			Cooked pasta				Cooking test		
			Real variables		Color			Color			Cutting Force	OCT	Weight gain	Solids loss
Test	**Coded variable**		w:w (g:g)	g/100g	L*	a*	b*	L*	a*	b*	N	s	g/100 g	g/100 g
	x_1	**x_2**	**X_1 WGF:RWF**	**X_2 YNC**										
YP1	-1	-1	60:40	1	48.46	10.19	36.01	47.91	5.88	20.54	1.54	240	93.01	3.56
YP2	1	-1	70:30	1	51.03	10.01	36.04	46.76	6.91	20.98	1.74	210	89.66	3.60
YP3	-1	1	60:40	2	48.52	11.30	40.28	47.63	6.16	25.76	1.28	240	95.52	3.71
YP4	1	1	70:30	2	44.64	11.51	37.93	44.22	6.26	21.80	1.35	210	77.42	3.78
YP5	0	0	65:35	1.5	47.89	11.06	38.50	47.46	5.88	22.16	1.20	240	74.97	3.64
YP6	0	0	65:35	1.5	46.52	11.11	37.69	48.67	6.37	23.79	1.42	240	93.63	3.74
YP7	0	0	65:35	1.5	44.51	11.33	36.61	47.85	5.77	22.08	1.35	240	90.34	3.79
	y_1	**y_2**	**Y_1 WGF:RWF**	**Y_2 PNC**										
PP8	-1	-1	60:40	1	39.49	13.94	9.59	44.33	6.28	8.07	1.21	240	104.06	4.20
PP9	1	-1	70:30	1	38.31	14.15	10.46	42.81	7.02	8.83	1.47	210	91.61	4.01
PP10	-1	1	60:40	2	34.49	16.77	4.14	38.17	8.28	5.26	1.38	210	95.47	4.05
PP11	1	1	70:30	2	32.72	16.65	4.84	38.25	7.48	5.27	1.34	210	96.22	4.30
PP12	0	0	65:35	1.5	34.43	15.15	6.78	40.84	7.22	6.14	1.41	240	102.24	4.47
PP13	0	0	65:35	1.5	36.65	15.71	7.07	40.71	6.87	6.24	1.32	240	106.80	4.41
PP14	0	0	65:35	1.5	34.31	15.72	6.77	40.27	7.11	5.89	1.45	240	96.06	4.15

WGF: whole grain wheat flour; RWF: refined wheat flour; YNC: yellow natural concentrate; PNC: pink natural concentrate; YP: yellow pasta; PP: pink pasta; OCT: optimal cooking time.

Table 2. Mathematical models and averages obtained from experimental design for yellow (YP) and pink (PP) pastas

	Technological characteristics				Mathematical model[a]	R^2	Fcal/Ftab	p-value
YP[b]	Raw	Color		L*	47.37	0.64	0.19	0.32
				a*	$a^*raw=10.93+0.65^*x_2$	0.82	3.43	0.005
				b*	37.58	0.68	1.58	0.02
	Cooked	Color		L*	47.21	0.68	0.23	0.27
				a*	6.18	0.61	0.17	0.36
				b*	22.45	0.48	0.68	0.09
		Cutting force		N	1.41	0.66	0.21	0.30
		Cooking test	Weight gain	g/100 g	87.79	0.48	0.10	0.53
			Solids loss	g/100 g	3.69	0.61	0.17	0.36
PP[c]	Raw	Color		L*	$L^*raw=35.77-2.65^*y_2$	0.78	2.68	0.01
				a*	$a^*raw=15.44+1.33^*y_2$	0.97	19.05	<0.001
				b*	$b^*raw=7.09-2.77^*y_2$	0.99	25.01	<0.001
	Cooked	Color		L*	$L^*cooked=40.77-2.68^*y_2$	0.99	14.79	<0.001
				a*	$a^*cooked=7.18+0.62^*y2-0.39^*y_1y_2$	0.94	4.70	0.003
				b*	$b^*cooked=6.53-1.59^*y_2$	0.88	5.60	0.002
		Cutting force		N	1.37	0.71	0.26	0.25
		Cooking test	Weight gain	g/100 g	98.92	0.45	0.09	0.56
			Solids loss	g/100 g	4.23	0.31	0.05	0.74

[a] When model was not significant, an average value is presented.

[b] YP: yellow pasta, [c] PP: pink pasta

x_1: (-1, 0, 1) correspond to (60:40, 65:35, 70:30 WGF:RWF w:w), where WGF: whole grain wheat flour; RWF: refined wheat flour

x_2: (-1, 0, 1) correspond to (1, 1.5, 2 g YNC/100 g flour mixture), where YNC: yellow natural concentrate

y_1: (-1, 0, 1) correspond to (60:40, 65:35, 70:30 WGF:RWF w:w)

y_2: (-1, 0, 1) correspond to (1, 1.5, 2 g PNC/100 g flour mixture), where PNC: pink natural concentrate

The variation in the proportion between refined and whole wheat flour did not significantly affect the pastas characteristics, which opens up the possibility of producing pastas with varied nutrient contents, principally fibers.

Both results obtained for YP and PP are quite positive, indicating that it could be possible to obtain colored pastas, by variating YNC and PNC concentrations, with no effects on their technological properties.

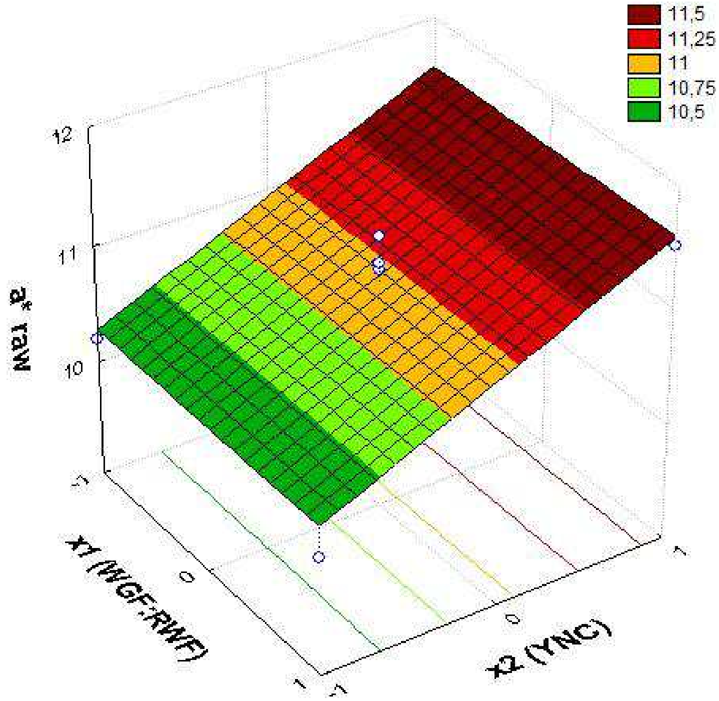

Figure 1. Response Surface from experimental design for color parameter a* of raw yellow pasta (YP)
x_1: (-1, 0, 1) correspond to (60:40, 65:35, 70:30 WGF:RWF w:w), where WGF: whole grain wheat flour; RWF: refined wheat flour
x_2: (-1, 0, 1) correspond to (1, 1.5, 2 g YNC/100 g flour mixture), where YNC: yellow natural concentrate

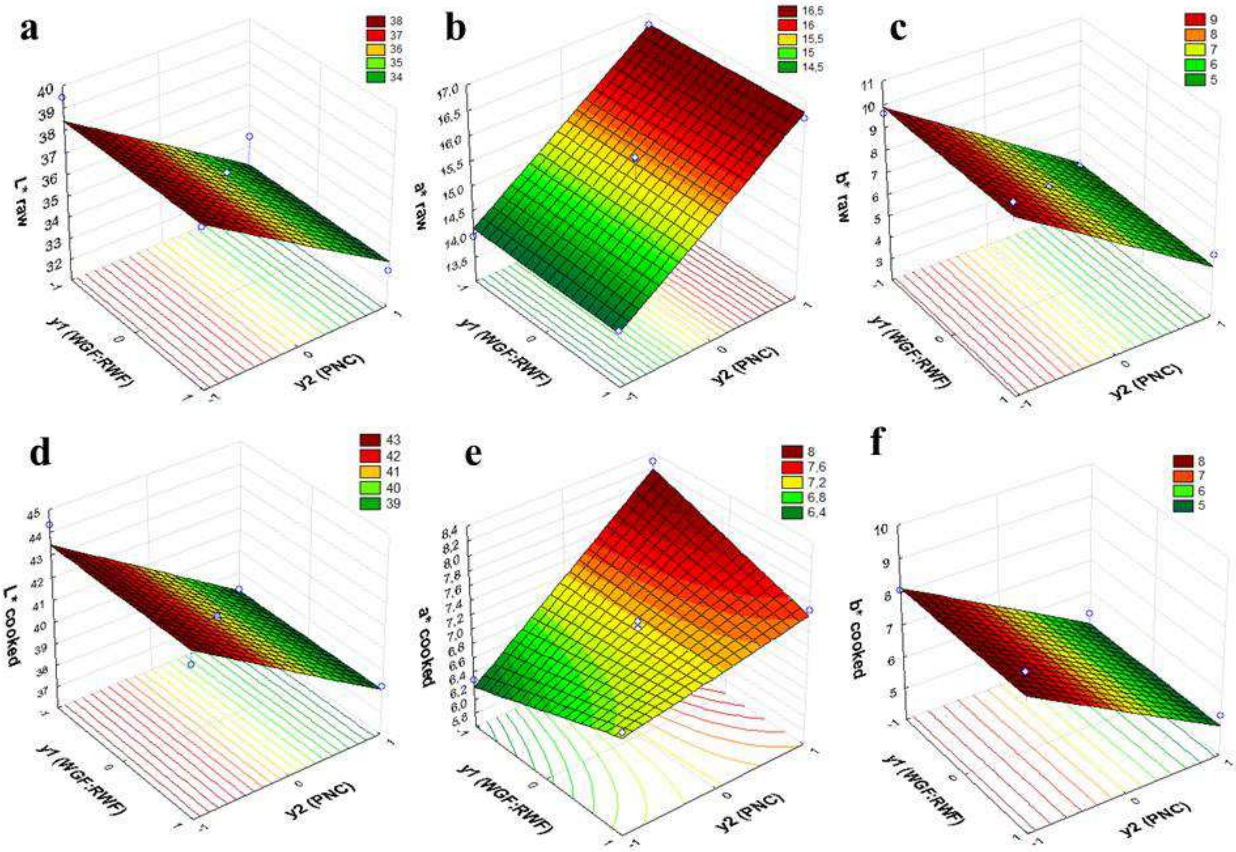

Figure 2. Response surfaces from experimental design for pink pasta (PP). a) Color L* for raw PP; b) Color a* for raw PP; c) Color b* for raw PP; d) Color L* for cooked PP; e) Color a* for cooked PP; f) Color b* for cooked PP

y_1: (-1, 0, 1) correspond to (60:40, 65:35, 70:30 WGF:RWF w:w), where WGF: whole grain wheat flour; RWF: refined wheat flour

y_2: (-1, 0, 1) correspond to (1, 1.5, 2 g PNC/100 g flour mixture), where PNC: pink natural concentrate

3.3 Selection of colored whole wheat pastas

PCA was done to select pastas with similar properties to CP. Figure 3 shows the result from PCA done for all 15 formulations. While principal component 1 (PC1) explains 58.53% of the correlation between the analyzed properties, PC2 presented 33.02%, which in sum explain 91.55% of the correlation between properties. Encircled pastas CP, YP1, and PP9, located near to the control, presented more similar technological characteristics (texture, weight gain and solids loss), which means they would behave homogeneously when cooked together. Even though YP6 was also located near to CP, it was not chosen because it was a central point from the experimental design (0, 0), but its replicates did not present good repeatability (YP5 and YP7). The three selected pastas can be seen in Figure 4.

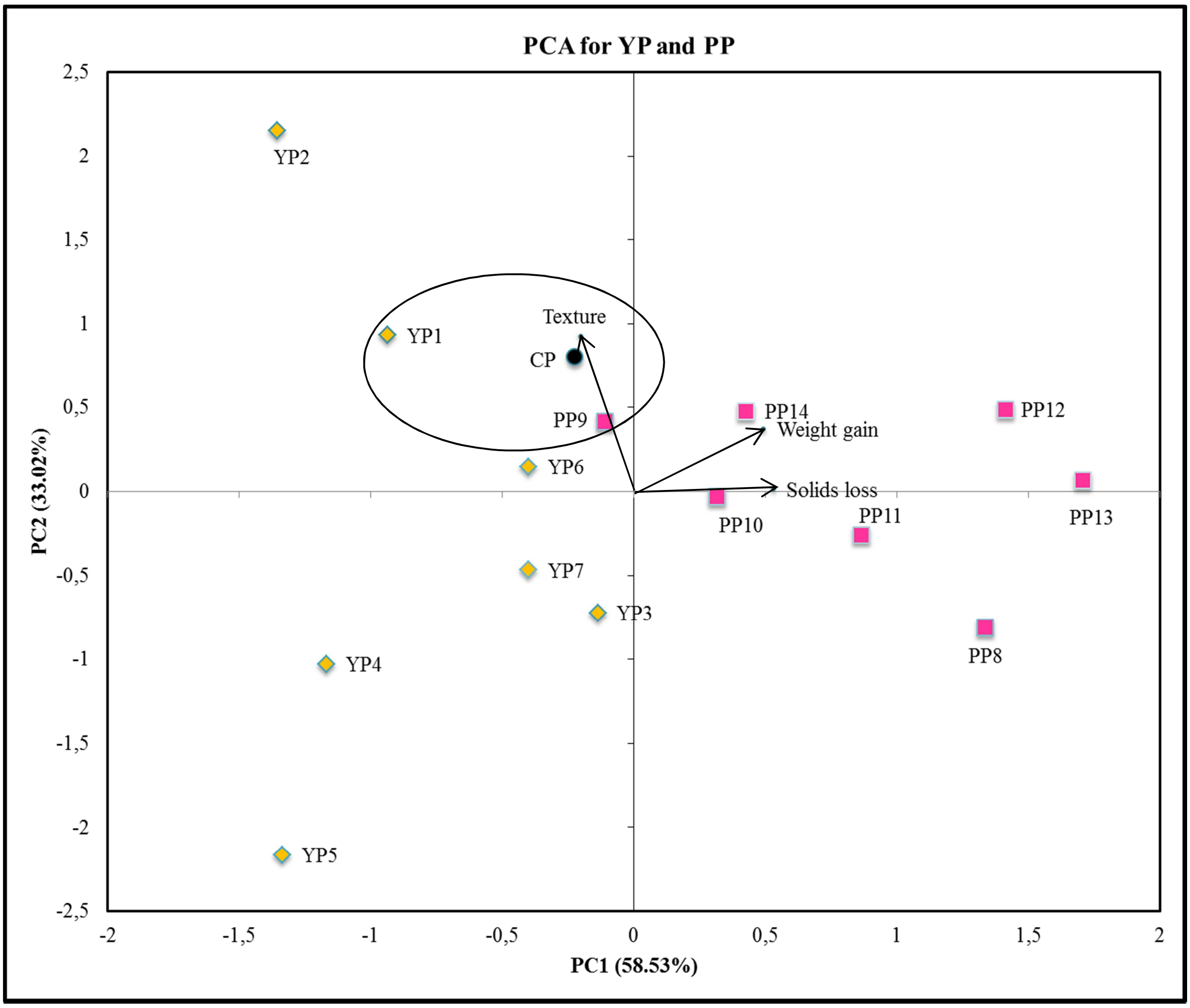

Figure 3. Principal components analysis of the pastas (Where ●=CP; ◇=YP1 to 7; ■=PP8 to 14). Formulations encircled correspond to: CP: Control pasta 70:30 WGF:RWF w:w; YP1: yellow pasta (60:40 WGF:RWF w:w, 1 g YNC/100 g flour mixture); PP9: pink pasta (70:30 WGF:RWF w:w, 1 g PNC/100 g flour mixture).

Figure 4. Raw material preparation, pasta extrusion and dry hanging for fresh control, yellow, and pink pasta

3.4 Proximate composition and antioxidant capacity of CP, YP1 and PP9

The three selected pastas (CP, YP1, and PP9) presented in average 30.13 g of moisture/100 g. When compared between them, in dry basis, the three pastas presented no significant differences, with 13.74 g of protein, 0.85 g of fat, and 7.09 g of fiber in 100 g sample. Due to the fact that YP1 had a lower proportion of WGF (60:40 WGF:RWF w:w) than CP and PP9, it presented, in dry basis, a significantly lower ash content ($p \leq 0.05$) (1.81 ± 0.07 g/100 g), in comparison to CP (1.94 ± 0.03 g/100 g), and PP9 (1.89 ± 0.02 g/100 g). This occurred because the highest percentages of minerals are found in the outer parts of the grain (Doblado-Maldonado et al., 2012). Sobota, Rzedzicki, Zarzycki, & Kuzawinska (2015) also obtained significantly higher ash content in pasta production with 40% of common wheat bran and 60% of durum wheat (1.39 ± 0.02 g/100 g), in comparison to pasta with 20% of common wheat bran and 80% of durum wheat (1.11 ± 0.01 g/100 g).

It is expected that the three pastas contain higher fiber content than refined wheat pasta, as the values reported by the USDA Agricultural Research Service (2015), where cooked refined wheat spaghetti contains 1.8 g of fiber/100 g, while cooked whole wheat spaghetti has 3.9 g of fiber/100 g.

The three selected pastas presented brownish (CP), yellowish (YP1) and pink color (PP9) (see Figure 4). Color measurements indicated big differences to control: ΔE^*_{ab} of raw YP1 and PP9 with respect to CP were 12.82 and 15.47, respectively, while ΔE^*_{ab} of cooked YP1 and PP9 with respect to CP decreased to 6.40 and 9.03, still presenting clear differences to the human eye.

We further analyzed antioxidant activity of the pastas, for evaluating the effect of the natural colored concentrates on this property of whole wheat pasta.

Figure 5 shows the pastas antioxidant capacities, observing that CP presented similar values to the other pastas. This is due to the use of WGF, which, according to Adom, Sorrells, & Liu (2005), presents naturally a higher TPC than RWF (662.86 vs. 185.50 μmol of gallic acid equiv./100 g), as well as hydrophilic antioxidant activity (2.48 vs 0.58 μmol of vitamin C equiv/g) and lipophilic antioxidant activity (594.24 vs. 55.00 nmol of vitamin E equiv/g).

Figure 5, letter A, shows that the total phenolics content (TPC) of PP9 was significantly higher ($p \leq 0.05$) than CP and YP1, both in raw and cooked pasta (raw PP9: 121.28 μg GAE/g db, cooked PP9: 104.03 μg GAE/g db). The increase of TPC due to the use of colored ingredients in pastas was also confirmed by Khan et al. (2013), who determined a TPC value of 1.88 ± 0.11 mg GAE/g db, in uncooked durum wheat pasta containing 20% of red sorghum flour, in comparison to 0.77 ± 0.07 mg GAE/g of TPC in uncooked durum wheat pasta.

The cooking process caused no significant variation ($p \leq 0.05$) of TPC content for CP and YP1, while it was significant for PP9 decreasing 14.22%. As seen, the addition of PNC caused a significantly higher TPC in PP9 even with a concentration as low as 1%. This could be caused by the natural components present in it (apple, purple sweet potato, radish and cherry), all known for their antioxidant properties.

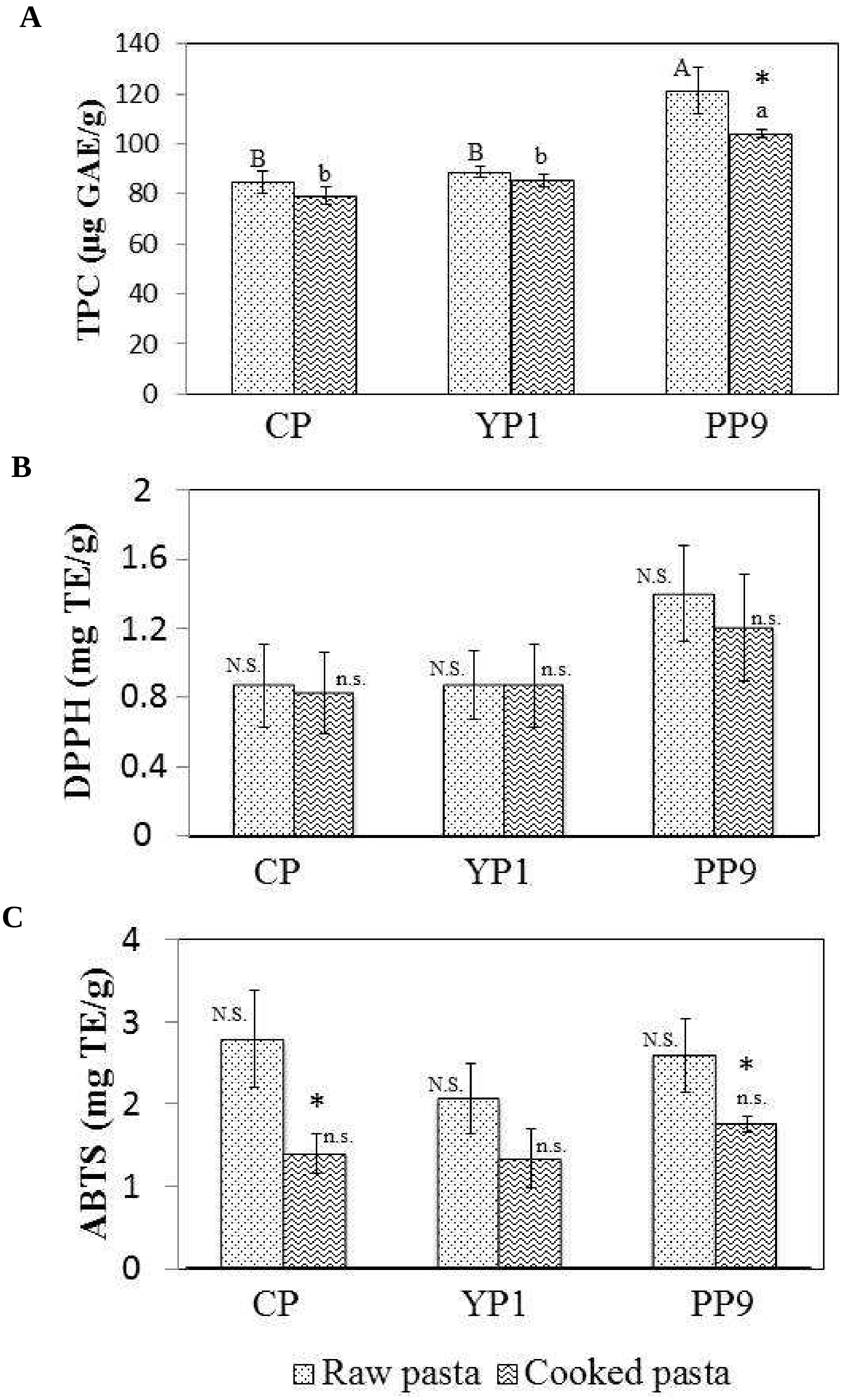

Figure 5. Antioxidant analysis of fresh raw and cooked pastas (dry basis): A) Total phenolics content (TPC), B) DPPH and C) ABTS antioxidant capacities. Formulations correspond to: CP: control pasta (70:30 WGF:RWF w:w); YP1: yellow pasta (60:40 WGF:RWF w:w, 1 g YNC/100 g flour mixture); PP9: pink pasta (70:30 WGF:RWF w:w, 1 g PNC/100 g flour mixture). Columns with different letters (upper (raw pasta) or lower case (cooked pasta)) in the same graph differ significantly ($p \leq 0.05$). N.S. not significant / * indicates significant difference between raw and cooked values ($p \leq 0.05$).

Figure 5, letter B, indicates that DPPH scavenging capacity of the three pastas presented no significant difference between them, neither in the raw nor cooked form; furthermore, there was no significant decrease ($p \leq 0.05$) in this capacity after cooking for all pastas.

Figure 5, letter C, shows that ABTS scavenging capacity presented a similar trend to the DPPH test, being not significantly different for the three pastas, both in the raw and cooked form ($p \leq 0.05$); the cooking process caused a significant reduction in this capacity for CP and PP9 (49.85 and 32.35%, respectively), being not significant for YP1.

We observed that the addition of YNC may increase the antioxidant capacity of whole wheat pasta, to the same levels than 70% of WGF may do, given that YP1 contains only 60% of WGF, while CP and PP9 had 70% WGF in their formulation. Furthermore, YNC may have protected antioxidant compounds present in whole wheat pasta, as the cooking process did not significantly affect the results of YP1, obtaining in the three cases high antioxidant capacity retention.

In this work, the use of natural colored concentrates in whole wheat pastas modifies their color, while maintaining pasta technological properties and antioxidant capacity.

4. Conclusion

The use of natural colored concentrates is a viable alternative for the production of whole wheat pasta, containing different colors and functional bioactives, with no addition of artificial colorants, and without modifying the technological and antioxidant properties of whole wheat pasta. Their application facilitates the whole use of whole wheat, benefiting all the productive chain stages and diversifying the offer of whole grain products.

5. Acknowledgements

Authors thank the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq) for the scholarship for Adriana Lucia Wahanik, *Fundação de apoio ao ensino, pesquisa e extensão (FAEPEX)* from UNICAMP, and Mario Slikta, from GNT Brasil, for kindly providing samples of natural concentrates for this study. We also thank Nathanny Alves, Nayara Castro and Igor Borges for their valuable help at the experimental stage.

6. References

AACC International. (2010). *Approved Methods of Analysis* (11th ed.). St. Paul: AACC International.

Adom, K. K., Sorrells, M. E., & Liu, R. H. (2005). Phytochemicals and antioxidant activity of milled fractions of different wheat varieties. *Journal of Agricultural and Food Chemistry*, *53*(6), 2297–306. doi:10.1021/jf048456d

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. doi:10.1016/S0023-6438(95)80008-5

Doblado-Maldonado, A. F., Pike, O. A., Sweley, J. C., & Rose, D. J. (2012). Key issues and challenges in whole wheat flour milling and storage. *Journal of Cereal Science*, *56*(2), 119–126. doi:10.1016/j.jcs.2012.02.015

Jonnalagadda, S. S., Harnack, L., Liu, R. H., McKeown, N., Seal, C., Liu, S., & Fahey, G. C. (2011). Putting the whole grain puzzle together: health benefits associated with whole grains--summary of American Society for Nutrition 2010 Satellite Symposium. *The Journal of Nutrition*, *141*(5), 1011S–22S. doi:10.3945/jn.110.132944

Khan, I., Yousif, A., Johnson, S. K., & Gamlath, S. (2013). Effect of sorghum flour addition on resistant starch content, phenolic profile and antioxidant capacity of durum wheat pasta. *Food Research International*, *54*(1), 578–586. doi:10.1016/j.foodres.2013.07.059

Kill, R. C. (2001). Additional ingredients. In R. C. Kill & K. Turnbull (Eds.), *Pasta and semolina technology*. Oxford: Blackwell Science Ltd.

Madi, L., Costa, A. C. P. B., & Rego, R. A. (2010). *BRASIL FOOD TRENDS 2020*. São Paulo.

Manthey, F. A., & Schorno, A. L. (2002). Physical and cooking quality of spaghetti made from whole wheat durum. *Cereal Chemistry*, *79*(4), 504–510. doi:10.1094/CCHEM.2002.79.4.504

Neto, B. B., Scarminio, I. S., & Bruns, R. E. (2010). *Como fazer experimentos: Pesquisa e desenvolvimento na Ciência e na Indústria*. Porto Alegre: Bookman.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1998). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology & Medicine*, *26*(98), 1231–1237.

Roesler, R., Carrasco, L. C., Holanda, R. B., Alves, C., Sousa, S., & Pastore, G. M. (2007). Atividade antioxidante de frutas do cerrado. *Ciênc. Tecnol. Aliment.*, *27*(1), 53–60.

Slavin, J. (2003). Why whole grains are protective: biological mechanisms. *The Proceedings of* *the Nutrition Society*, *62*(1), 129–34. doi:10.1079/PNS2002221

Sobota, A., Rzedzicki, Z., Zarzycki, P., & Kuzawinska, E. (2015). Application of common wheat bran for the industrial production of high-fibre pasta. *International Journal of Food Science and Technology*, *50*, 111–119. doi:10.1111/ijfs.12641

Stevens, L. J., Burgess, J. R., Stochelski, M. a, & Kuczek, T. (2014). Amounts of artificial food dyes and added sugars in foods and sweets commonly consumed by children. *Clinical Pediatrics*, 1–13. doi:10.1177/0009922814530803

USDA Agricultural Research Service, N. D. L. (2015). *USDA National Nutrient Database for Standard Reference, Release 28*. Retrieved from http://www.ars.usda.gov/nea/bhnrc/ndl

THIRD ARTICLE: TURMERIC AND PURPLE SWEET POTATO: NEW SOURCES OF FIBER AND ANTIOXIDANTS FOR WHOLE WHEAT PASTA

Adriana Lucia Wahanik, Iramaia Angélica Neri-Numa, Glaucia Maria Pastore, Yoon Kil Chang, Maria Teresa Pedrosa Silva Clerici

Article submitted to the "*Journal of the Science of Food and Agriculture*"

TURMERIC AND PURPLE SWEET POTATO: NEW SOURCES OF FIBER AND ANTIOXIDANTS FOR WHOLE WHEAT PASTA

Adriana Lucia Wahanik[a], Iramaia Angélica Neri-Numa[b], Glaucia Maria Pastore[b], Yoon Kil Chang[a], Maria Teresa Pedrosa Silva Clerici[a]*,

[a]*Food Technology Department, School of Food Engineering, University of Campinas (UNICAMP), 13083-862, Campinas, São Paulo, Brazil*

[b]*Food Science Department, School of Food Engineering, University of Campinas (UNICAMP), 13083-862, Campinas, São Paulo, Brazil*

*Corresponding author. Tel.: +55 19 3521 4000. E-mail address: mclerici@unicamp.br

Abstract

The demand for *clean-label* and functional foods has increased, as response to non-communicable diseases. We aimed to develop colored fresh pastas containing whole wheat flour (WGF), refined wheat flour (RWF) and turmeric flour (TF) or purple sweet potato flour (SPF). We made 3 control pastas (CP), 7 turmeric pastas (TP) and 7 sweet potato pastas (SPP). Selected pastas were CP3 (70:30 WGF:RWF w:w), TP6 (60:40 WGF:RWF w:w, 5 g TF/100 g fm) and SPP13 (60:40 WGF:RWF w:w, 9 g SPF/100 g fm), with similar technological properties and high average dietary fiber (7.92 g/100 g db). Raw TP6 presented highest total phenolics content (534.46 ± 1.93 µg GAE/ g db), DPPH (5.70 ± 0.10 mg TE/ g db), and ABTS (9.02 ± 0.58 mg TE/ g db), with high retention of antioxidant capacity after cooking. Combination of tubers and whole wheat can have health benefits and be an alternative with environmental sustainability.

Keywords: clean-label, fresh pasta, healthiness, sustainability

Chemical compounds used in this article:

Methanol (PubChem CID: 887); Ethanol (PubChem CID: 702); Folin-Ciocalteau reagent, 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) (PubChem CID: 2735032), 2,2-azinobis (3-ethyl-benzothiazoline-6-sulfonic acid) (ABTS) (PubChem CID: 9570474), gallic acid (PubChem CID: 370), and 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox) (PubChem CID: 40634).

Abbreviations

NCDs= non-communicable diseases

RSM= Response Surface Methodology

w= weight

db= dry basis

fm= flour mixture

p= significance level

ANOVA= Analysis of variance

1. Introduction

According to the World Health Organization (WHO, 2015), non-communicable diseases (NCDs) include cardiovascular diseases, cancers, respiratory diseases, and diabetes, and they have four risk factors in common: tobacco use, physical inactivity, abuse of alcohol, and unhealthy diets. New food developments for avoiding NCDs include the use of ingredients with health effects in highly consumed products, such as pasta, which production accounts to more than 3 million tons/year, and its consumption varies between 8 to 26 kg per capita/year, for the top-ten consuming countries (IPO, 2013). The use of whole wheat in combination with regional tubers in pastas may bring economic and health benefits.

Economic benefits refer to whole use of wheat for human food, given that there are only five major wheat producers in the world (European Union, China, India, Russia, USA) (Statista, 2015). Wheat losses could be reduced by the use of whole wheat, since conventional milling process removes wheat bran and germ, being refined wheat flour approximately 75% of the total grain, depending on the extraction rate. On the other hand, developing countries are major producers of tubers, due to climate and soil conditions. Turmeric and purple sweet potato have an estimated production of 8 and 110.7 million tons/year, respectively (Agropedia, 2014; Faostat, 2013). In order to stimulate their consumption, their processing and application in highly consumed products may have positive impact in agricultural business, thus increasing their added-value, and promoting environmental sustainability due to whole use of wheat and tubers.

Pasta has been proposed as vehicle for the inclusion of fibers and antioxidants, due to its convenience and low price for consumers, but its modification presents several difficulties, as some ingredients may affect pasta color, structure, cooking properties and final product texture (Brennan, 2008). Thus, it can be an alternative to put together the benefits of whole wheat, with those from turmeric and purple sweet potato. Whole wheat is an important source of phytochemicals, principally present in the bran and germ, and less in the starchy endosperm. Those phytochemicals include phenolic compounds, carotenoids, vitamin E, lignans, β-glucan, sterols and stanols (Adom et al., 2005; Liu, 2007). Turmeric, the rhizome of the herb *Curcuma longa*, with a particular flavor and yellow color, contains turmerin, essential oils and curcuminoids (phenolic compounds) (Sharma, Gescher, & Steward, 2005). Purple sweet potato (*Ipomoea batatas* Lam.), with purple color and sweet flavor, is rich in anthocyanins (Cevallos-Casals & Cisneros-Zevallos, 2004), and phenolic compounds (Teow et al., 2007). The association of fibers and different bioactive compounds may bring benefits to a greater portion of the population, improving healthiness of a highly consumed product.

Some authors have added sweet potato flour to pasta (Limroongreungrat & Huang, 2007; Singh, Raina, Bawa, & Saxena, 2004) and noodles (Collado & Corke, 1996; Shan, Zhu, Peng, & Zhou, 2013); however, up to the present time and to the best of our knowledge, no study has reported the use of turmeric and purple sweet potato in whole wheat pasta.

In this study, we aimed to produce and evaluate pastas containing whole wheat, turmeric, and purple sweet potato flours, for obtaining a healthier product with environmental sustainability.

2. Material and methods

2.1 Material

Whole grain wheat flour (WGF) and refined wheat flour (RWF), both from *Triticum aestivum*, were obtained from Moinho Anaconda (São Paulo, Brazil), turmeric flour (TF) was purchased from Cooperaçafrão (Mara Rosa, Brazil), and purple sweet potato was bought in the local market; it was washed, cut, blanched, lyophilized, and ground to obtain purple sweet potato flour (SPF). Chemical reagents ABTS, gallic acid, DPPH radical, and Trolox solution were purchased from Sigma-Aldrich (St. Louis, USA). Folin-Ciocalteau phenol reagent was obtained from Dinâmica (Diadema, Brazil), and methanol and ethanol were purchased from Synth (Diadema, Brazil).

2.2 Chemical and technological analysis of raw materials

AACC International methods (2010) were used for proximate composition analysis of WGF, RWF, TF, and SPF, including moisture (method 44-15.02), protein (method 46-13.01) (factor 5.7 for wheat flours; factor 6.25 for turmeric and purple sweet potato), ether extract (method 30-25.01), dietary fiber (method 32-07.01), and ash content (method 08-01.01). Digestible carbohydrates were calculated by difference.

Rheological analysis of the WGF and RWF included extensigraph (method 54-10.01), and farinograph analysis (method 54-21.01).

Instrumental color of raw materials was measured using a Miniscan XE 3500 colorimeter (Hunterlab, Reston, VI, USA). Results are given in terms of L*, a* and b* values, where L* indicates lightness, a* value indicates (+) redness to (-) greenness, and b* value indicates (+) yellowness to (-) blueness.

2.3 Whole fresh pastas processing and evaluation

2.3.1 Control pasta: natural color

WGF and RWF in proportions of 60:40, 65:35, and 70:30 w:w, were used as control formulations, named as CP1, CP2, and CP3, respectively. For all tests, flours where mixed for two minutes in a Pastaia II (2 kg capacity) (Italvisa, Tatuí, Brazil), water was added (44 g/100 g flour mixture) during two minutes and mixed for additional 13 minutes, left to rest for 5 minutes, and then pasta was extruded, through a 1.8 mm diameter die, to obtain spaghetti. Fresh pasta was hung in polyvinyl chloride (PVC) tubes and partially dried with cold air for 30 minutes, packed in low density polyethylene (LDPE) bags, white pigmented with 1.5% titanium dioxide (Plastunion Indústria de Plásticos Ltda., Caieiras, Brazil), closed using a packing machine (200B, Selovac, São Paulo, Brazil), and stored under refrigeration (4°C) for 24 hours before further analysis.

Differences in control pastas were evaluated by one-way analysis of variance (ANOVA) followed by Tukey´s multiple comparison test ($p \leq 0.05$).

2.3.2 Turmeric and purple sweet potato whole pasta

Table 2 presents 17 formulations, 14 of them were made according to linear experimental design with axial points (-1, +1), and three replicates at the central point (0, 0). For Turmeric Pasta (TP) the variables were WGF:RWF (X1) (60:40 to 70:30 w:w), and TF (X2) (1 to 5 g/100 g flour mixture), and for Purple Sweet Potato Pasta (SPP) they were WGF:RWF (Y1) (60:40 to 70:30 w:w), and SPF (Y2) (3 to 9 g/100 g flour mixture). All pastas were produced as previously described in item 2.3.1.

2.3.3 Measurement of pasta chemical and technological properties

Cooking test of pasta was done for the calculation of the optimal cooking time (OCT), weight gain, and solids loss, according to method 66-50.01 (AACC International, 2010). Cooked pasta for analysis was obtained after determination of the OCT. Instrumental color of raw and cooked pasta was measured as indicated in item 2.2. An additional term, ΔE^*_{ab}, was calculated as $\Delta E^*_{ab} = [\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}]^{1/2}$, where each delta corresponds to the difference in the color parameter between two samples. Texture, measured in cutting force of cooked pasta, was evaluated with a TA.XT2 Texture Analyzer (Stable Micro Systems, Surrey, England), with a Light Knife Blade (A/LKB) probe, following method 66-50.01 (AACC International, 2010). Proximate composition of raw pastas was determined as indicated in item 2.2.

For TP and SPP, data from the experimental design was evaluated through the Response Surface Methodology (RSM) for regression coefficients and analysis of variance (ANOVA, $p \leq 0.05$), with minimal determination coefficient (R^2) of 0.80 (Neto et al., 2010).

2.4 Selection of formulations to obtain colored whole pastas

With the intention of finding three formulations [control pasta (CP), turmeric pasta (TP), and sweet potato pasta (SPP)] with similar technological characteristics, a Principal Components Analysis (PCA) was performed for finding the correlations between the different components of weight gain, solids loss and pasta cutting force, after the cooking test, for all pasta formulations. Data from PCA was plotted in a biplot.

2.5 Extraction and determination of total phenolic contents of selected fresh pastas

Total phenolics content (TPC) was determined using the Folin-Ciocalteau method (Roesler et al., 2007). For extraction, each sample of fresh pasta, both raw and cooked, was lyophilized (Liotop LP820, Liobras, São Carlos, Brazil), ground and dissolved in methanol for obtaining a 0.5 mg/mL pasta extract solution. 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 reaction at 50°C, absorbance at 760 nm was read in a spectrophotometer (DU-640™, Beckman-Coulter-Brea, CA, USA). Standard concentrations of gallic acid (0.3125 to 50 µg/mL) were used to prepare a calibration curve and the results were expressed as micrograms of gallic acid equivalents (µg GAE/g) in dry basis.

2.6 DPPH• scavenging assay of selected fresh pastas

DPPH free radical scavenging activity was measured using a method adapted by Brand-Williams, Cuvelier, & Berset (1995). The DPPH solution (0.004% w/v) was prepared in methanol and stored under refrigeration. Absorbance was measured and adjusted to 1.0 ± 0.2 at 517 nm using the spectrophotometer. A standard curve was built with Trolox (25 to 200 µM). An aliquot of 100 µL pasta extract (prepared in item 2.5) 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 a blank. Results are expressed in mg Trolox Equivalent (TE)/g in dry basis.

2.7 Radical cation ABTS scavenging capacity of selected fresh pastas

The radical cation ABTS scavenging capacity was measured using the method described by Re et al (1999). Briefly, ABTS was dissolved in distilled 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 16 h before use. An aliquot of 2 mL was diluted in 100 mL of ethanol, and adjusted 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 standard (final concentration 3.125 to 125µM) in ethanol; absorbance was read 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 (prepared as in item 2.5) 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 a blank. Results are expressed in mg Trolox Equivalent (TE)/g in dry basis.

ANOVA and Tukey´s multiple comparison test were used for evaluation TPC and antioxidant capacity of selected pastas ($p \leq 0.05$).

2.8 Statistical analysis

All analyses were performed in triplicate, except for cutting force analysis which was done in quintuplicate. Statistical analyses were carried out using the software Statistica 7.0 (StatSoft, Tulsa, USA). For the selection of the best formulations, PCA analysis was made using SAS software version 9.02 (SAS Institute, North Carolina, USA).

3. Results and discussion

3.1 Chemical and technological analysis of raw materials

Table 1 presents proximate composition of raw materials. As expected, WGF presented a higher protein, fat, ash and fiber content than RWF, Betschart (1988) explained this fact by the presence of the bran and germ of the grain, not removed during the milling process. Protein value of RWF (12.68 ± 0.84 g/100 g dry sample) fit the requirements of the Codex Standard for wheat flour, as well as the recommendations from Posner & Hibbs (2005), that establish protein content of wheat flour for pasta processing variating between 12.5 and 15%.

TF presented higher fiber content (20.27 ± 1.09 g fiber/100 g dry basis) than the other raw materials. Additionally, this value is a lot higher than the 9.48 g fiber/100 g dry basis, found for turmeric by Leonel & Cereda (2002). The same authors reported a fiber content of SPF of 4.31 g fiber/100 g dry basis, which is lower than the one found in our study (9.62 ± 0.39 g fiber/100 g dry basis). In both cases, the difference in fiber contents could be due to the roots varieties, plantation conditions, and processing. This shows that TF and SPF can contribute with additional fiber to whole wheat fresh pasta, thus bringing benefits to consumers.

Farinographic results, Table 1, show a higher water absorption in WGF than RWF. The farinographic stability for RWF was superior to 23 min, which according to Pizzinato (1997), corresponds to a very strong flour. This has positive consequences, since a stronger flour will present a better pasta cooking quality (Feillet & Dexter, 1996), and will support the addition of other ingredients (Bloksma & Bushuk, 1988).

Table 1. Proximate composition and rheological characterization of raw materials

		RAW MATERIALS [a,b]			
Proximate composition (g/100 g in dry basis)		**WG**	**RWF**	**TF**	**SPF**
Protein		13.32±0.52	12.68±0.84	6.09±0.13	5.30±0.12
Fat		1.96±0.16	1.42±0.17	1.06±0.09	0.71±0.06
Ashes		1.61±0.02	0.68±0.02	6.81±0.05	1.83±0.04
Carbohydrates	Fiber	10.38±1.31	2.89±0.17	20.27±1.09	9.62±0.39
	Digestible carbohydrates [c]	72.73	82.33	65.77	82.54
Rheological parameters					
Farinograph	Water Absorption (%)	65.3	58.2	nd[d]	nd[d]
	Stability (min)	15.5±0.9	23.1±0.8		
Extensograph	Resistance to extension (FU)(45 min)	434±28	525±35	nd[d]	nd[d]
	Extensibility (45 min)	105±7.5	125±7		

[a] WGF: Whole grain wheat flour; RWF: Refined wheat flour; TF: Turmeric flour; SPF: Purple sweet potato flour.
[b] Raw materials WGF, RWF, TF, and SPF presented 9.97, 10.90, 10.80, and 3.45 g/100 g moisture, respectively.
[c] Calculated by difference.
[d] nd: not determined.

Extensigraph analysis indicated lower resistance to extension, and extensibility in WGF than in RWF. However, both flours could be classified as medium-strength, as their resistance to extension is in between the extremes for weak and strong flour (130 and 560 BU, respectively) (Pizzinato, 1997). These parameters would indicate a reduced pasta deformation and breakage in the drying step, especially from spaghetti which is dried hanging.

These differences between WGF and RWF could be due to the presence of non-starch polysaccharides in bran from WGF, which cause a high water retention capacity of the dough, and the dilution of wheat proteins by bran and its interference in the protein matrix, according to Zhang & Moore (1997) and Manthey (2002).

3.2 Evaluation of technological characteristics from pastas

Table 2 presents technological parameters obtained for CP1, CP2 and CP3. All raw control pastas were brownish and had no significant differences in color parameters. When cooked, pastas presented a lighter brown color, with decrease in redness and yellowness (indicated by a* and b* parameters). In the other technological parameters (cooking loss, weight gain, and cutting force), CP2 and CP3 presented similar quality, and CP1 had the biggest difference with them, presenting a significantly lower weight gain. CP3 is the only formulation that fits FDA "whole grain" recommendation, with a final 53.8% of whole grain, in wet basis, since a food to be defined as "whole grain product", it must contain minimum 51% of whole grain (FDA, 1999).

For turmeric pasta (TP), Table 3 and Figure 1 show that TF increased the yellowness of raw pasta (b*) (Fig 1a), but when cooked, pastas had a decrease in their luminosity (L*) (Fig 1b), and an increase in their redness (a*) (Fig 1c), highlighting their yellow color. This behavior could be explained by the strong yellow color of TF (L*=55.86 ± 0.67, a*=28.49 ± 0.23, b*=68.84 ± 0.58). The principal pigment from TF is curcumin, which is normally insoluble in water, but when solubilized and in presence of water, it becomes heat sensitive (Downham & Collins, 2000).

The other analyzed technological characteristics of TP remained unaltered, indicating that it would be possible to formulate a product containing TF with desired color parameters, and with the same characteristics of cutting force, weight gain and solids loss than CP.

The purple color of the SPF (L*=53.46 ± 0.78, a*=15.08 ± 0.35, b*= -8.74 ± 0.17) produced pastas with dark purple color. Table 3 and Figure 1 show that SPF increased raw pasta redness (a*) (Figure 1d), and decreased raw pasta yellowness (b*) (Figure 1e), but cooking produced pastas with a lighter purple color, independently from SPF concentration. Anthocyanins are the predominant pigments in purple sweet potato (Cuevas Montilla, Hillebrand, & Winterhalter, 2011), whose color depends on pH value, are heat sensitive and subject to oxidation (Mapari et al., 2005).

Table 2. Technological properties of pastas containing whole wheat, turmeric flour, and purple sweet potato flour[1]

					Raw pasta			Cooked pasta				Cooking test		
			Real variables		Color			Color			Cutting Force	OCT	Weight gain	Solids loss
Test[2]	**Coded variables**		w:w	g/100g	L*	a*	b*	L*	a*	b*	N	s	g/100 g	g/100 g
CP1			60:40		48.40±0.48^{ns}	10.57±0.09^{B}	23.24±0.09^{ns}	49.81±0.17^{ns}	7.22±0.30^{ns}	14.92±0.46^{ns}	1.61±0.08^{A}	210	69.18±4.92^{B}	3.17±0.31^{B}
CP2			65:35		47.15±1.42^{ns}	11.10±0.17^{AB}	23.73±0.27^{ns}	49.59±0.79^{ns}	7.22±0.11^{ns}	14.63±0.71^{ns}	1.39±0.13^{B}	240	79.76±8.00^{AB}	3.80±0.13^{A}
CP3			70:30		46.25±0.17^{ns}	11.37±0.36^{A}	23.43±0.73^{ns}	49.79±0.48^{ns}	7.20±0.10^{ns}	14.57±0.12^{ns}	1.52±0.11^{AB}	270	92.78±5.78^{A}	3.95±0.16^{A}
	x_1	**x_2**	**X_1 WGF:RWF**	**X_2 TF**										
TP4	-1	-1	60:40	1	42.93	13.41	43.94	44.49	8.34	36.09	1.66	210	87.08	3.79
TP5	1	-1	70:30	1	43.49	12.74	43.92	44.37	8.78	39.59	1.88	210	100.15	3.96
TP6	-1	1	60:40	5	42.73	13.99	47.71	37.36	14.52	42.43	1.53	210	94.43	4.00
TP7	1	1	70:30	5	44.45	13.94	48.65	38.57	14.17	41.68	1.98	210	85.26	3.91
TP8	0	0	65:35	3	42.55	14.40	47.33	39.46	11.85	40.79	1.62	210	96.01	3.93
TP9	0	0	65:35	3	41.66	13.64	44.81	40.25	11.82	40.68	1.82	210	89.95	3.81
TP10	0	0	65:35	3	43.71	14.17	47.15	40.50	11.68	41.01	1.93	240	95.27	4.11
	y_1	**y_2**	**Y_1 WGF:RWF**	**Y_2 SPF**										
SPP11	-1	-1	60:40	3	45.50	10.87	18.76	46.28	6.39	11.39	1.49	210	83.19	4.08
SPP12	1	-1	70:30	3	43.65	11.12	19.06	45.75	7.54	13.20	1.53	210	84.26	4.04
SPP13	-1	1	60:40	9	41.33	12.31	12.60	42.28	6.78	8.34	1.66	210	79.17	4.44
SPP14	1	1	70:30	9	43.64	11.96	12.42	45.77	7.50	9.92	1.57	240	95.45	4.54
SPP15	0	0	65:35	6	41.54	11.69	16.23	43.08	6.41	9.46	1.40	210	89.67	4.43
SPP16	0	0	65:35	6	44.06	11.83	15.27	44.63	6.82	10.12	1.93	210	86.24	4.35
SPP17	0	0	65:35	6	43.02	12.10	15.41	43.12	6.53	9.60	1.59	210	84.52	4.50

[1] WGF: Whole grain wheat flour; RWF: Refined wheat flour; TF: Turmeric flour; SPF: Purple sweet potato flour, CP: Control pasta; TP: Turmeric pasta; SPP: Purple sweet potato pasta; OCT: Optimal cooking time.

[2] Values for CP1 to CP3 are expressed as mean ± standard deviation, and when followed by different letters in the same column are significantly different ($p \leq 0.05$), and ns: no significant difference ($p \leq 0.05$).

Table 3. Mathematical models and averages obtained from experimental design for turmeric pastas (TP) and purple sweet potato pastas (SPP)

	Technological characteristics				Mathematical model[1]	R^2	Fcal/Ftab	p-value
TP	Raw	Color		L*	43.07	0.37	0.06	0.67
				a*	13.76	0.56	0.14	0.43
				b*	$b^*raw=46.21+2.13^*x_2$	0.80	2.95	0.0069
	Cooked	Color		L*	$L^*cooked=40.71-3.23^*x_2$	0.92	9.04	0.0006
				a*	$a^*cooked=11.59+2.89^*x_2$	0.99	69.59	<0.001
				b*	40.33	0.70	1.73	0.02
		Cutting Force		N	1.77	0.71	0.26	0.24
		Cooking test	Weight gain	g/100 g	92.59	0.73	2.00	0.02
			Solids loss	g/100 g	3.93	0.35	0.06	0.69
SPP	Raw	Color		L*	43.25	0.69	0.24	0.27
				a*	$a^*raw=11.70+0.57^*y_2$	0.79	2.89	0.0072
				b*	$b^*raw=15.68-3.2^*y_2$	0.99	50.55	<0.001
	Cooked	Color		L*	44.42	0.67	0.22	0.28
				a*	6.85	0.67	0.22	0.29
				b*	10.29	0.68	1.58	0.02
		Cutting Force		N	1.60	0.10	0.01	0.95
		Cooking test	Weight gain	g/100 g	$Wgain=86.07+4.34^*y_1+3.80^*y_1y_2$	0.82	1.30	0.03
			Solids loss	g/100 g	4.34	0.77	2.53	0.01

[1] When model was not significant, an average value is presented.

x1: (-1, 0, 1) correspond to (60:40, 65:35, 70:30 WGF:RWF w:w), x2: (-1, 0, 1) correspond to (1, 3, 5 g TF/100 g flour mixture), y1: (-1, 0, 1) correspond to (60:40, 65:35, 70:30 WGF:RWF w:w), y2: (-1, 0, 1) correspond to (3, 6, 9 g SPF/100 g flour mixture), WGF: Whole grain wheat flour; RWF: Refined wheat flour; TF: Turmeric flour; SPF: Purple sweet potato flour

Figure 1f shows that WGF:RWF (y1) and the interaction between WGF:RWF and SPF (y1*y2) increased the weight gain of cooked SPPs. The raw materials WGF and SPF contain fiber and starch (Table 1) that may be the cause of the higher water retention in the cooked pasta. These results agree with the ones found by Foschia et al. (2015), who included up to 15% of dietary fibers in fresh durum pasta, with a minimum OCT of 6.5 minutes, and obtained average weight gain values of 111.10 g/100 g. All pastas in this study presented cooking losses bellow 8 g/100 g, which is the limit for acceptable quality described by Dick & Youngs (1988), cited by Foschia, Peressini, Sensidoni, Brennan, & Brennan (2015).

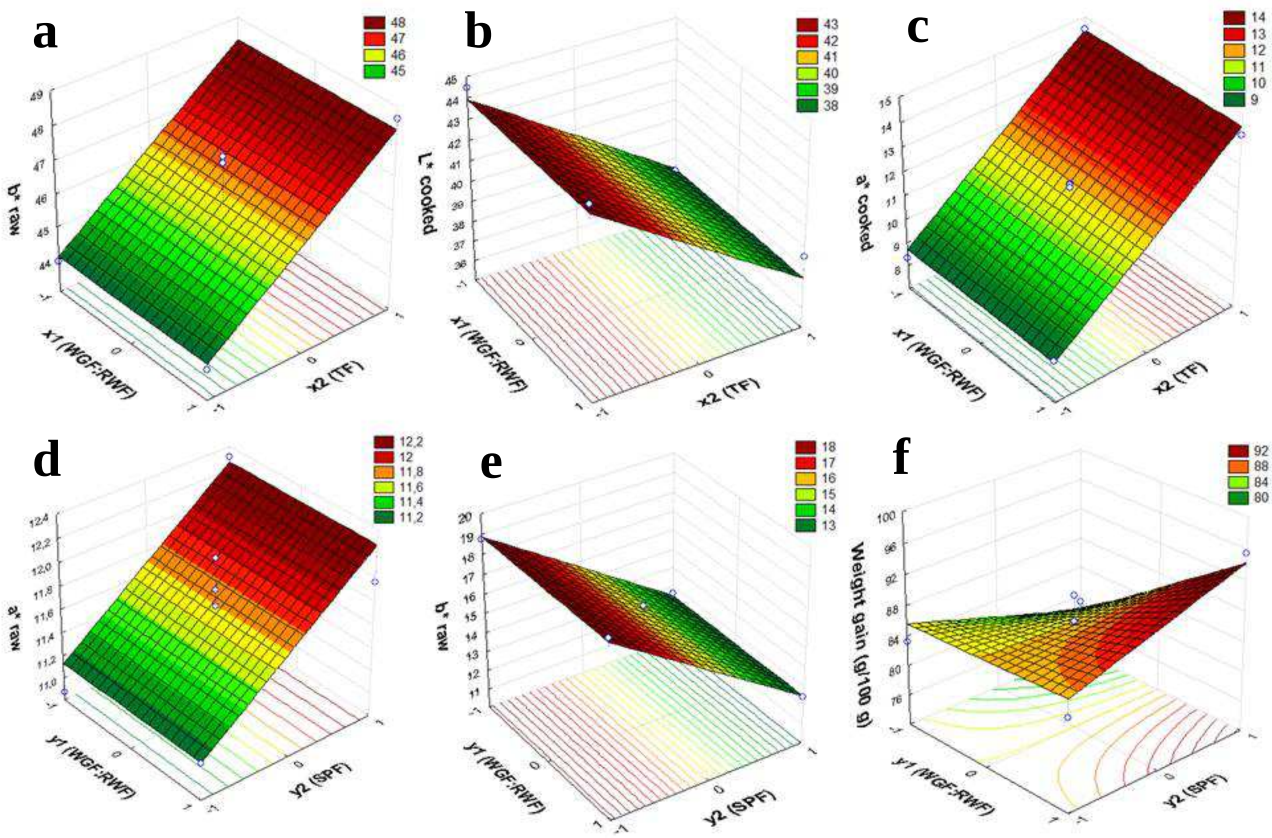

Figure 1. Response surfaces from experimental design for turmeric pastas (TP) and purple sweet potato pastas (SPP). a) Color b* for raw TP; b) Color L* for cooked TP; c) Color a* for cooked TP; d) Color a* for raw SPP; e) Color b* for raw SPP; f) Weight gain for cooked SPP.
x1: (-1, 0, 1) correspond to (60:40, 65:35, 70:30 WGF:RWF w:w)
x2: (-1, 0, 1) correspond to (1, 3, 5 g TF/100 g flour mixture)
y1: (-1, 0, 1) correspond to (60:40, 65:35, 70:30 WGF:RWF w:w)
y2: (-1, 0, 1) correspond to (3, 6, 9 g SPF/100 g flour mixture)
WGF: Whole grain wheat flour; RWF: Refined wheat flour; TF: Turmeric flour; SPF: Purple sweet potato flour

3.3 Selection of whole wheat pastas with tubers

PCA was done to select pastas with similar properties between them. The PCA of the data (Figure 2) revealed that 81.45% of the variation sources could be described by two PCs: PC1 (46.89%) and PC2 (34.56%), indicating that it could be used for pastas selection. Three formulations, CP3, TP6, and SPP13 were located near each other, which means they have similar technological properties (cutting force, weight gain and solids loss); these pastas were selected (Figure 3), for further analyzes of proximate composition and antioxidant properties. However, only CP3 fits FDA "whole grain" recommendation, with a final 53.8% of whole grain, while TP6 and SPP13 are below the minimum of 51% of whole grain content.

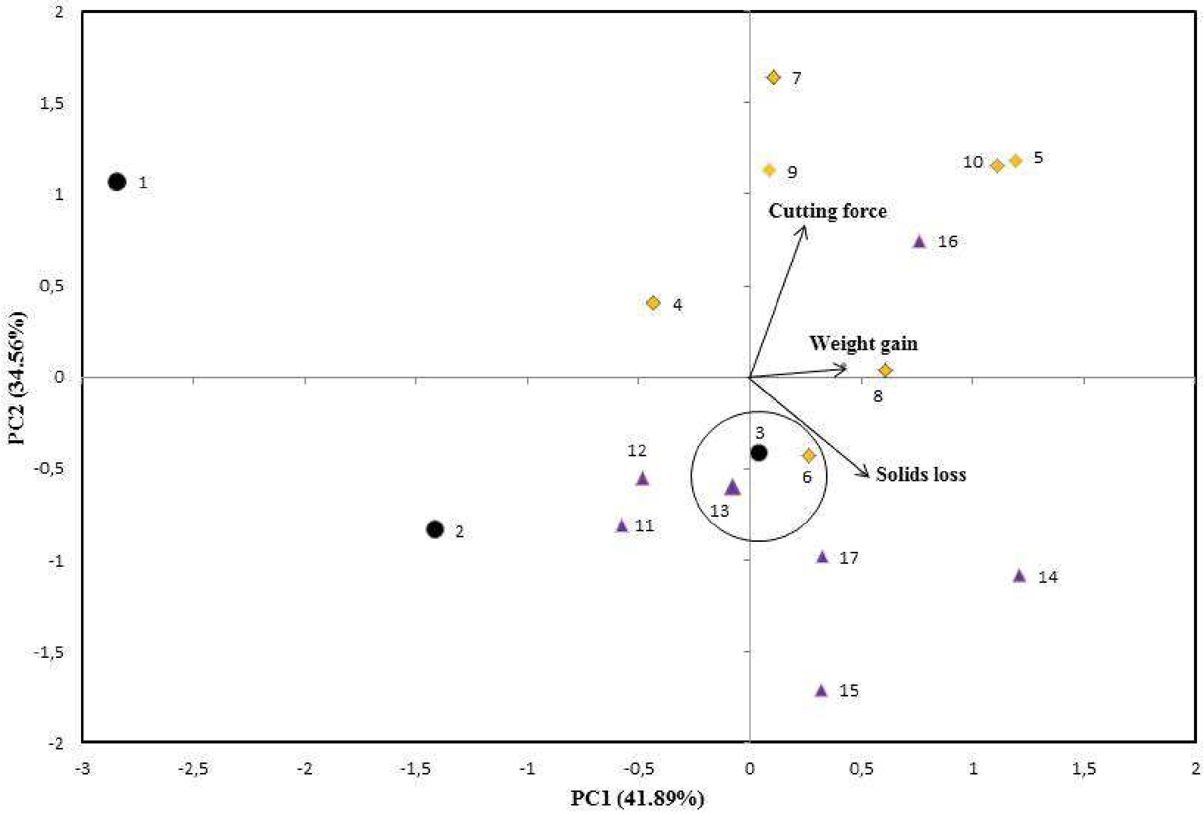

Figure 2. Principal components analysis of the pastas (Where numbers 1 to 3, correspond to CP, represented by ●; numbers 4 to 10 correspond to TP, represented by ◇; numbers 11 to 17 correspond to SPP, represented by ▲). Formulations encircled correspond to: 3→CP3: Control pasta 70:30 WGF:RWF w:w; 6→TP6: Turmeric pasta (60:40 WGF:RWF w:w, 5 g TF/100 g fm); 13→SPP13: Purple sweet potato pasta (60:40 WGF:RWF w:w, 9 g SPF/100 g fm).

Figure 3. Processing of control, turmeric and purple sweet potato fresh whole wheat pastas

Selected pastas presented brown, yellow and purple colors (CP3, TP6, and SPP13, respectively) (Figure 3). It is important that selected pastas may present different color parameters that assure a clear differentiation between them, for establishing colored pasta in the market that consumers may clearly identify, and that this color difference will continue after cooking. According to Sharma (2003), values of ΔE^*_{ab} higher than 2.3 between two samples are detected by human eye as color differences. Thus, we calculated ΔE^*_{ab} values for raw pastas, obtaining ΔE^*_{ab} of 24.7 between CP3 and TP6, 11.9 between CP3 and SPP13, and 35.2 between TP6 and SPP13. After cooking, the value for ΔE^*_{ab} increased between CP3 and TP6 (31.4), it decreased between CP3 and SPP13 (9.8), and remained almost the same between TP6 and SPP13 (35.3).

3.4 Proximate composition and antioxidant capacity of selected pastas

Pastas CP3, TP6, and SPP13 presented in average 30.36 g of moisture/100 g. When compared between them, in dry basis, the three pastas presented no significant differences, with 13.30 g of protein, 0.87 g of fat, 7.92 g of fiber, and 75.93 g of digestible carbohydrates in 100 g sample. However, ash content presented significant differences ($p \leq 0.05$) between the three pastas, with 1.94 ± 0.03, 2.12 ± 0.03, and 1.89 ± 0.04 g/100 g in dry basis for CP3, TP6, and SPP13, respectively. The higher ash value for TP6 could have been directly affected by ash content in TF (Table 1).

Figure 4 shows the antioxidant capacity of both raw and cooked pastas, as well as the retention of this capacity after cooking.

The analysis of TPC showed that raw TP6 presents the highest value of phenolics content (534.46 ± 1.93 µg GAE/ g db), being it more than six times the value present in CP3, and almost three times the value found in SPP13. TPC retention after cooking was superior to 87.0% in all pastas. SPP13 presented the lowest TPC retention after cooking, which, according to Fares et al. (2010), could be related to the degradation of phenolic compounds to oxidation caused by oxygen, water and heat.

The decreases in TPC found in this study were lower than the ones observed by Fares et al. (2010), who enriched durum wheat pasta with different wheat bran fractions; after pasta cooking, they obtained a reduction in free phenolic acids ranging between 9.3 and 39%. Similarly, Hirawan et al. (2010) obtained an average 40% reduction in TPC after cooking of regular and whole wheat commercial pastas.

DPPH scavenging capacity of pastas presented a similar trend as the one seen with TPC analysis, with TP6 showing the highest values (5.70 ± 0.10 mg TE/ g db), being it almost eight times the value for CP3 and more than three times the value for SPP13. TP6 presented an increase in DPPH value of 115.34% after cooking.

Raw TP6 presented the highest ABTS scavenging capacity (9.02 ± 0.58 mg TE/ g db), being it more than six times the capacity for CP3, and more than three times the value for SPP13. This same tendency was observed after cooking.

TPC of fiber-containing pastas presented high values in the study made by Sun-Waterhouse et al. (2013), due to the addition of elderberry juice concentrate (EJC); the highest TPC was found in raw pasta containing EJC and low methoxyl pectin (2.110 ± 0.012 mg Catechin Equivalent/g db). Biney & Beta (2014) also observed an increase in TPC values in pasta formulations with buckwheat bran addition, with respect to control pasta. Boroski et al. (2011) showed that addition of 10% of oregano leaves and 10% of carrot leaves caused the highest TPC (283.22 mg GAE/100 g) in cooked pasta, as well as high DPPH scavenging capacity. These results agree with the findings in our work, where turmeric and purple sweet potato contributed to increase the antioxidant capacity of whole wheat pasta.

From the three antioxidants tests, it is possible to see that TP6 possesses the highest antioxidant capacity of all samples, both in raw as in cooked pastas, while SPP13 presents the second place in antioxidant capacity. In comparison to CP3, which contains only WGF, the pastas containing turmeric (TP6) and purple sweet potato (SPP13) presented higher antioxidant capacities after cooking, which shows, in this work, that it is possible to use regional tubers for color modification of whole wheat pasta, while making them more attractive to consumers, and with no alterations on their technological properties. An additional benefit is the increase in variety of compounds with antioxidant capacity, given the differences between the ingredients of the pastas (whole wheat, turmeric, purple sweet potato).

The developed colored whole wheat pastas had no artificial colorants, were rich in antioxidants and fiber, and were done with whole use of agricultural products, thus possessing a great potential for the food market as a *clean-label* and functional food.

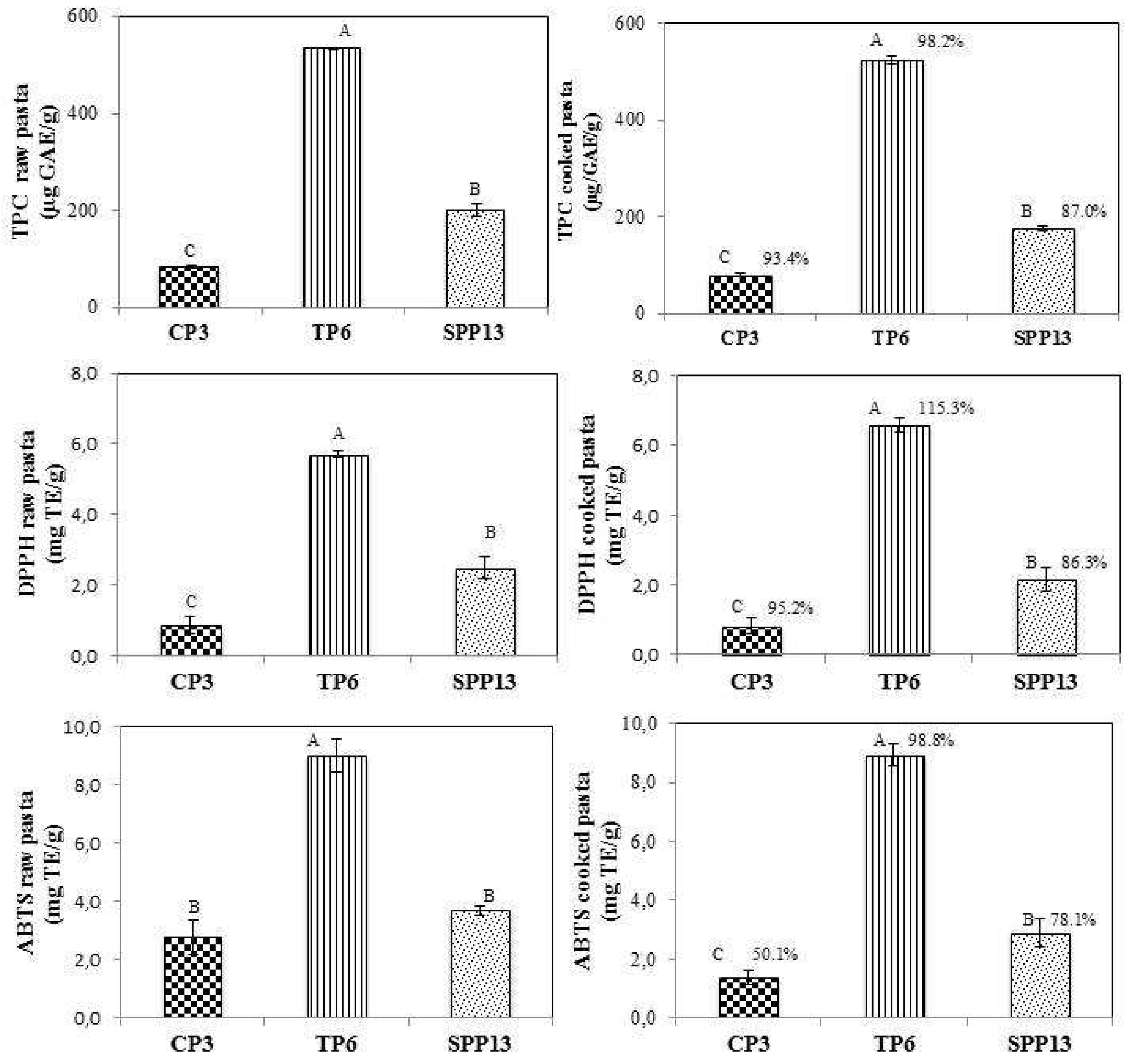

Figure 4. Antioxidant analysis of fresh raw and cooked pastas (dry basis): Total phenolics content (TPC), DPPH and ABTS antioxidant capacities.

Where formulations correspond to: CP3→ Control pasta 70:30 WGF:RWF w:w; TP6: Turmeric pasta (60:40 WGF:RWF w:w, 5 g TF/100 g fm); SPP13: Purple sweet potato pasta (60:40 WGF:RWF w:w, 9 g SPF/100 g fm). Columns with different letters in the same graph differ significantly ($p \leq 0.05$). Percent value indicated in each column for cooked pastas graphs (on the right) indicate percent of retention of the antioxidant capacity with respect to raw pasta for each formulation.

4. Conclusion

Pastas containing whole wheat, turmeric and purple sweet potato were developed, with benefits such as *clean-label* due to the absence of artificial additives, rich in antioxidants and fiber, sustainable and related to social causes, and with whole use of agricultural products.

5. Acknowledgements

Authors thank the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (*CNPq*), Brazil, for the scholarship for Adriana Lucia Wahanik, and *Fundação de apoio ao ensino, pesquisa e extensão (FAEPEX)* from UNICAMP. Authors appreciate the collaboration at the experimental stage from Nathanny Alves, Nayara Castro and Igor Borges.

6. Conflict of interest

We confirm that there are no conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

7. References

AACC International. (2010). *Approved Methods of Analysis* (11th ed.). St. Paul: AACC International.

Adom, K. K., Sorrells, M. E., & Liu, R. H. (2005). Phytochemicals and antioxidant activity of milled fractions of different wheat varieties. *Journal of Agricultural and Food Chemistry*, *53*(6), 2297–306. doi:10.1021/jf048456d

Agropedia. (2014). Turmeric price forecast. Retrieved from http://agropedia.iitk.ac.in/content/turmeric-price-forecast-1

Biney, K., & Beta, T. (2014). Phenolic profile and carbohydrate digestibility of durum spaghetti enriched with buckwheat flour and bran. *LWT - Food Science and Technology*, *57*(2), 569–579. doi:10.1016/j.lwt.2014.02.033

Bloksma, A. H., & Bushuk, W. (1988). Rheology and chemistry of dough. In Y. Pomeranz (Ed.), *Wheat: Chemistry and technology* (3rd ed.). St. Paul: AACC.

Boroski, M., Aguiar, A., Boeing, J., Rotta, E., Wibby, C., Bonafé, E., Souza, N., Visentainer, J. (2011). Enhancement of pasta antioxidant activity with oregano and carrot leaf. *Food Chemistry*, *125*(2), 696–700. doi:10.1016/j.foodchem.2010.09.068

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. doi:10.1016/S0023-6438(95)80008-5

Brennan, C. S. (2008). High-fibre pasta products. In B. R. Hamaker (Ed.), *Technology of functional cereal products*. Cambridge: Woodhead Publishing Limited.

Cevallos-Casals, B. a, & Cisneros-Zevallos, L. (2004). Stability of anthocyanin-based aqueous extracts of Andean purple corn and red-fleshed sweet potato compared to synthetic and natural colorants. *Food Chemistry*, *86*(1), 69–77. doi:10.1016/j.foodchem.2003.08.011

Collado, L. S., & Corke, H. (1996). Use of wheat-sweet potato composite flours in yellow-alkaline and white-salted noodles. *Cereal Chemistry*, *73*(4), 439–444. Retrieved from http://cat.inist.fr/?aModele=afficheN&cpsidt=3183295

Cuevas Montilla, E., Hillebrand, S., & Winterhalter, P. (2011). Anthocyanins in Purple Sweet Potato (Ipomoea batatas L .) Varieties. *Fruit, Vegetable and Cereal Science and Biotechnology*, *5*, 19–24.

Dick, J. W., & Youngs, V. L. (1988). Evaluation of durum wheat, semolina, and pasta in the United States. *US Agriculture Department*.

Downham, A., & Collins, P. (2000). Colouring our foods in the last and next millennium. *International Journal of Food Science & Technology*, *35*, 5–22.

Faostat. (2013). Sweet potato statistical data. Retrieved from http://faostat3.fao.org/browse/Q/QC/E

Fares, C., Platani, C., Baiano, A., & Menga, V. (2010). Effect of processing and cooking on phenolic acid profile and antioxidant capacity of durum wheat pasta enriched with debranning fractions of wheat. *Food Chemistry*, *119*(3), 1023–1029. doi:10.1016/j.foodchem.2009.08.006

FDA. (1999). Health Claim Notification for Whole Grain Foods. FDA. Retrieved from http://www.fda.gov/Food/IngredientsPackagingLabeling/LabelingNutrition/ucm073639.htm

Feillet, P., & Dexter, J. E. (1996). Quality requirements of durum wheat for semolina milling and pasta production. In J. E. Kruger, R. B. Matsuo, & J. W. Dick (Eds.), *Pasta and noodle technology* (pp. 95–131). St. Paul, Minnesota, USA: American Association of Cereal Chemists, Inc.

Foschia, M., Peressini, D., Sensidoni, A., Brennan, M. A., & Brennan, C. S. (2015). How combinations of dietary fibres can affect physicochemical characteristics of pasta. *LWT - Food Science and Technology*, *61*(1), 41–46. doi:10.1016/j.lwt.2014.11.010

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. doi:10.1016/j.foodchem.2009.06.022

IPO. (2012). The world pasta industry status report 2012. Roma: International Pasta Organisation. Retrieved from http://www.internationalpasta.org/index.aspx?Lang=2

Leonel, M., & Cereda, M. P. (2002). Caracterização físico-química de algumas tuberosas amiláceas. *Ciênc. Tecnol. Aliment. Campinas*, *22*(1), 65–69.

Limroongreungrat, K., & Huang, Y.W. (2007). Pasta products made from sweetpotato fortified with soy protein. *LWT - Food Science and Technology*, *40*(2), 200–206. doi:10.1016/j.lwt.2005.09.012

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

Manthey, F. A. (2002). Processing and quality of whole-wheat pasta. In L. Marquart, J. L. Slavin, & R. G. Fulcher (Eds.), *Whole-grain foods in health and disease*. St. Paul: AACC.

Mapari, S. A. S., Nielsen, K. F., Larsen, T. O., Frisvad, J. C., Meyer, A. S., & Thrane, U. (2005). Exploring fungal biodiversity for the production of water-soluble pigments as potential natural food colorants. *Current Opinion in Biotechnology*, *16*, 231–238. doi:10.1016/j.copbio.2005.03.004

Neto, B. B., Scarminio, I. S., & Bruns, R. E. (2010). *Como fazer experimentos: Pesquisa e desenvolvimento na Ciência e na Indústria*. Porto Alegre: Bookman.

Pizzinato, A. (1997). *Qualidade da farinha de trigo: conceito, fatores determinantes e parámetros de avaliação e controle*. Campinas: Instituto de Tecnologia de Alimentos.

Posner, E. S., & Hibbs, A. N. (2005). *Wheat flour milling* (2nd ed.). St. Paul, USA: AACC International.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1998). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology & Medicine*, *26*(98), 1231–1237.

Roesler, R., Carrasco, L. C., Holanda, R. B., Alves, C., Sousa, S., & Pastore, G. M. (2007). Atividade antioxidante de frutas do cerrado. *Ciênc. Tecnol. Aliment.*, *27*(1), 53–60.

Shan, S., Zhu, K.-X., Peng, W., & Zhou, H.-M. (2013). Physicochemical properties and salted noodle-making quality of purple sweet potato flour and wheat flour blends. *Journal of Food Processing and Preservation*, *37*, 709–716. doi:10.1111/j.1745-4549.2012.00686.x

Sharma, G. (Ed.). (2003). *Digital color imaging handbook*. Boca Raton, FL, USA: CRC Press.

Sharma, R. A., Gescher, A. J., & Steward, W. P. (2005). Curcumin: the story so far. *European*

Journal of Cancer, *41*, 1955–68. doi:10.1016/j.ejca.2005.05.009

Singh, S., Raina, C. S., Bawa, A. S., & Saxena, D. C. (2004). Sweet potato-based pasta product : optimization of ingredient levels using response surface methodology, (1988), 191–200.

Statista. (2015). Projected leading 10 wheat producers worldwide in 2014/2015. Retrieved September 30, 2015, from http://www.statista.com/statistics/237912/global-top-wheat-producing-countries/

Sun-Waterhouse, D., Jin, D., & Waterhouse, G. I. N. (2013). Effect of adding elderberry juice concentrate on the quality attributes, polyphenol contents and antioxidant activity of three fibre-enriched pastas. *Food Research International*, *54*(1), 781–789. doi:10.1016/j.foodres.2013.08.035

Teow, C. C., Truong, V.D., McFeeters, R. F., Thompson, R. L., Pecota, K. V., & Yencho, G. C. (2007). Antioxidant activities, phenolic and β-carotene contents of sweet potato genotypes with varying flesh colours. *Food Chemistry*, *103*(3), 829–838. doi:10.1016/j.foodchem.2006.09.033

WHO. (2015). *Noncommunicable Diseases Progress Monitor 2015*. Geneva.

Zhang, D., & Moore, W. R. (1997). Effect of wheat bran particle size on dough rheological properties. *Journal of the Science of Food and Agriculture*, *74*(4), 490–496. doi:10.1002/(SICI)1097-0010(199708)74:4<490::AID-JSFA822>3.0.CO;2-0

8. Appendix 1

Rheological parameters of WGF and RWF*

Rheological parameters			WGF	RWF
Farinograph	Water Absorption (%)		65.3	58.2
	Development time (min)		11.0±1.0	15.3±0.3
	Stability (min)		15.5±0.9	23.1±0.8
	Degree of softening (BU)		24.7±4.7	24.7±2.9
	Time to breakdown (min)		18.52±0.9	24.1±0.6
Extensigraph	R (FU)			
		45 min	434±28	525±35
		90 min	521±43	874±24
		135 min	636±41	998±53
	Rmax (FU)			
		45 min	436±25	705±5
		90 min	524±39	1003±40
		135 min	637±41	1056±30
	E (mm)			
		45 min	105±7.5	125±7
		90 min	94±7.2	105±5
		135 min	89±3.5	93±2
	A (cm^2)			
		45 min	68±4.5	112±6
		90 min	69±0.6	129±9
		135 min	78±2.6	117±7
	D (BU/mm)			
		45 min	4.2±0.5	4.2±0.5
		90 min	5.6±0.9	8.3±0.5
		135 min	7.2±0.7	10.7±0.4

*Extensigraph terms: R: resistance to extension; Rmax: Maximum resistance; E: Extensibility; A: Energy (cm^2); D: Resistance/Extensibility. BU= Brabender units

9. Appendix 2

Proximate composition of pastas in dry basis (g/100 g)*

		CP3	TP6	SPP13
Protein		13.39±0.51^{ns}	13.43±0.51^{ns}	13.07±0.0.60^{ns}
Fat		0.93±0.14^{ns}	0.81±0.05^{ns}	0.86±0.05^{ns}
Ashes		1.94±0.03^{B}	2.12±0.03^{A}	1.89±0.04^{C}
Carbohydrates	**Fiber****	8.15	8.01	7.60
	Digestible carbohydrates***	75.59	75.63	76.58

*Pasta formulations CP3, TP6, and SPP13 presented 30.14, 29.64, and 31.30 g/100 g moisture, respectively.
Values with no letters in common in the same line are significantly different (p≤0.05).
ns: not significant difference (p≤0.05).
**Calculated from raw materials.
***Calculated by difference.

GENERAL DISCUSSION

The aim of this work was the development of whole wheat pasta, rich in fiber and antioxidants, which may contribute to the solution for the increase in NCDs. Whole wheat pasta was selected, due to the fact that it has not been fully developed, due to alterations in color, texture, and cooking characteristics, therefore presenting an improvement opportunity.

As a first approach, a review on the topic functional pasta was done, to explore the state of the art and the advance in some areas. It showed that several studies have been undertaken for the addition of fiber, antioxidant compounds, and varied ingredients, for modifying pastas nutritional, technological, and antioxidant capacities, but more work is still missing in the development of whole wheat pasta with added ingredients, that may contribute with whole use of agricultural products. As solutions, we proposed more studies in the format and cooking processing of pastas, as they may facilitate the use of novel ingredients and offer more pasta varieties to consumers, as well as new combined sources of fiber and antioxidants. For this, tubers and roots were proposed as they can modify the nutritional and antioxidant profile of whole wheat pasta, while they promote the activity of small agricultural producers.

In the second article, the development of whole wheat pasta, containing commercially-available natural colored concentrates, without altering pastas technological characteristics and antioxidant capacity was presented. We obtained three formulations (CP, YP1 and PP9) that comply with this objective; furthermore, we obtained high dietary fiber content (6.64 to 7.31 g/100 g), and we observed that the addition of yellow and pink concentrates may retain and even increase total phenolic compounds and antioxidant activity of pastas. The use of natural colored concentrates is a viable alternative for the production of whole wheat pasta, with no addition of artificial colorants, and without affecting the technological properties of whole wheat pasta.

In the third article, turmeric and purple sweet potato were proposed as novel ingredients for use in whole wheat pasta, as sources of fiber and antioxidant compounds. Effectively, whole wheat pasta presented high dietary fiber content (average 7.92 g/100 g dry basis), and the use of turmeric presented the highest total phenolic contents, DPPH and ABTS, followed by purple sweet potato and control pasta. Thus, tubers and roots could be effectively used for modifying pastas color, improving nutritional and antioxidant profiles, without altering technological properties of pasta. Another advantage of the use of tubers and roots in whole wheat pasta is the effective promotion of agricultural business and support for small producers, as well as whole use of these types of products. Taking into consideration the results from our work, the use of other agricultural products is encouraged, as many benefits (nutritional, technological and antioxidant) can still be discovered.

CONCLUSION

The development of whole wheat pasta was possible by using natural colored concentrates, and turmeric and purple sweet potato flours, with the claims of fiber, antioxidant-rich food, and clean-label. Both sets of experiments presented excellent results. While the natural colored concentrates are a factible alternative for modifying the color of whole wheat pasta while adding functional value to it, making it healthier and *clean-label*, the combination of tubers and whole wheat can have health benefits and be an alternative with environmental sustainability and agricultural positive impact.

Taking into account the review and the whole wheat pastas developed, we can affirm that it is possible to make pastas healthier with the addition of functional ingredients, considering also the selection of the most suitable formats and cooking process of pastas to be offered to the consumer. Further researches on whole wheat pastas containing fiber, antioxidant compounds and other ingredients, such as roots and tubers, may bring new insights for reducing the risk of several NCDs.