Dysphagia management in Parkinson's disease – comparison of the effect of thickening agents on taste, aroma and texture.

Florence Baert [1,2], Geertrui Vlaemynck [1], Anne-Sophie Beeckman [3,4], Stephanie Van Weyenberg [1], Christophe Matthys[2,5]

[1] *Department Technology and Food, Flanders Research Institute for Agriculture, Fisheries and Food, Brusselsesteenweg 370 9090 Melle, Belgium*

[2] *Clinical and Experimental Endocrinology, Department of Chronic Diseases, Metabolism, KU Leuven, O&N I Herestraat 49 - box 902 3000 Leuven, Belgium*

[3] *Speech Language Therapy, Postgraduate Course Dysphagia Coordinator, Artevelde University of Applied Sciences, Campus Kantienberg, Voetweg 66 9000 Gent, Belgium*

[4] *Speech Language Therapy, AZ Maria Middelares, Buitenring Sint-Denijs 30, 9000 Gent*

[5] *Department of Endocrinology, University Hospitals Leuven, Campus Gasthuisberg, Herestraat 49 3000 Leuven, Belgium*

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Corresponding author: Geertrui.vlaemynck@ilvo.vlaanderen.be

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Abstract

Background & Aims

Dysphagia is a frequent symptom in Parkinson's Disease (PD). Thickening liquids facilitates safe swallowing, however low treatment compliance is a major issue, due to patients' dislike of thickened liquids. Some studies suggest a negative impact of gum-based thickeners, currently most used in clinical practice, on sensory properties compared to starch-based thickeners. This has not yet been investigated in PD. This study's aim was to compare taste, texture and aroma of gum-based and starch-based thickened soups in participants with PD.

Methods

Gum-based Resource Thicken Up Clear (RTUC) and starch-based kitchen products potato starch (PS) and quinoa flour (QF) were evaluated in broccoli soup. Texture, aroma and taste were characterized by rheology, volatile and sensory profiling. Thickened soups were evaluated in participants with PD and controls through a paired comparison test.

Results

Reduced release of 61.4%, 46.2% and 38.5% of volatiles was observed after thickening with RTUC, PS and QF respectively. Overall taste intensity was reduced in RTUC- and PS-thickened soup respectively. Taste and aroma of PS-thickened soup were considered more intense by respectively 70.3% and 63.8% of all participants (n=36 PD, n=41 controls),56.3%preferred the PS-thickened soup's texture . Taste and aroma of QF-thickened soup were considered more intense by respectively 68.1% and 65.6% of all participants (n=47 PD, n=31 controls), 58.0% preferred the QF-thickened soup's texture.

Conclusions

Starch-based thickeners demonstrated higher taste and aroma intensity . However, volatile and sensory profiling demonstrated reduced taste and aroma in all thickeners. Combining kitchen products with flavor enhancers may increase palatability of thickened beverages.

1. <u>Introduction:</u>

The majority of patients with Parkinson's disease (PD) will develop dysphagia throughout their disease (Ellerston, Heller, Houtz, & Kendall, 2016; Kalf, de Swart, Bloem, & Munneke, 2012). Dysphagia is a common non-motor symptom and results in a reduced quality of life, a higher risk of insufficient food, fluid or medication intake and aspiration pneumonia, one of the main causes of death in PD (Carneiro et al., 2014; Miller, Noble, Jones, & Burn, 2006; Suttrup & Warnecke, 2016). Texture modified food (TMF), softened solid foods and thickened liquids, is an important part of dysphagia management (van Hooren, Baijens, Voskuilen, Oosterloo, & Kremer, 2014). Because of the lack of standardized TMF terminology, the International Dysphagia Diet Standardisation initiative (IDDSI) published a framework in 2017 consisting of a continuum of 8 levels of consistency for both solid foods (3 – 7) and liquids (0 – 4). IDDSI is currently trying to implement this framework (the terminology, but also the IDDSI testing methods) worldwide, e.g. in Australia, Belgium, Brazil, Canada, China, Denmark… (Cichero et al., 2017).

For years, starch-based thickeners were used to modify flow properties of beverages and thereby facilitate safe swallowing in dysphagia (Mirro & Patey, 1991). Starch-thickened liquids, however, are not freeze-thaw stable, not amylase resistant, can have a grainy texture and increase post-swallowing residue at very thick consistencies (Matta, Chambers, Mertz Garcia, & McGowan Helverson, 2006; Vilardell, Rofes, Arreola, Speyer, & Clavé, 2016; Yuan & Thompson, 1998). The use of starches as kitchen products, e.g. potato starch, for general food preparation remains popular, but for TMF alternatives were sought (Rofes, Arreola, Mukherjee, Swanson, & Clavé, 2014; Williams & Phillips, 2009). At the start of the 21st century, a new generation of thickening blends based on various gums were developed to improve both storage stability and palatability (Rofes et al., 2014). Despite improvement of certain physicochemical parameters, dislike of sensory characteristics of thickened liquids results in low treatment compliance (Colodny, 2005; McCurtin et al., 2017; Shim, Oh, & Han, 2013). Reported compliance rates vary from 36% - 56.5%, with lower rates reported when it concerned outpatients (Shim et al., 2013).

Thickeners, such as hydroxypropyl methylcellulose (HPMC) and xanthan gum, reduce the perceived taste intensity (Bylaite, Adler-Nissen, & Meyer, 2005; David J. Cook, Hollowood, Linforth, & Taylor, 2002; D. J. Cook, Linforth, & Taylor, 2003; Ferry et al., 2006; Hollowood, Linforth, & Taylor, 2002; H. Kim, Hwang, Song, & Lee, 2017). Patients with PD often suffer from sensory deficits, 70-90% of patients with PD experience olfactory dysfunction (Double et al., 2003; J. Y. Kim, Lee, Chung, & Dhong, 2007; Mahlknecht et al., 2016). Less is known about taste dysfunction in PD, nonetheless some studies report a small but stable taste impairment (Oppo, Melis, Melis, Tomassini Barbarossa, & Cossu, 2020). Consequently reduced taste intensity caused by thickening agents may strengthen the loss of taste and smell. Although it has been demonstrated that thickening liquids have a negative impact on perceived taste, mouthfeel and aroma, to our knowledge this has not yet been investigated in patients with PD. Combining negative sensory properties with the risk for malnutrition in patients with PD, tasteful foods and beverages are important for maintaining food intake (Tomic et al., 2017).

There has been an evolution towards the use of gum-based thickeners, however limited studies are available that directly compare therapeutic or sensory qualities of gum- and starch-based thickeners (Matta et al., 2006; Vilardell et al., 2016). Contrary to the suggested improved texture, Nguyen *et al.* (2017) showed that not only starch, but also xanthan gum introduces a lumpy, grainy mouthfeel in skim yoghurt (Nguyen, Kravchuk, Bhandari, & Prakash, 2017). Reduced saltiness has been reported in a xanthan gum-thickened soup, compared to a starch-thickened soup (Abson et al., 2014). Similarly, higher aroma release, stronger milk flavor and a smoother texture was observed in a starch-thickened dessert compared to HPMC thickened (Arancibia, Castro, Jublot, Costell, & Bayarri, 2015). Therefore, we hypothesize that starch-based thickeners will have a higher taste/aroma intensity and improved texture pleasantness of thickened liquids compared to clinical gum-based thickeners. We opted for the use of starch-based kitchen products instead of the clinical modified starches, since food familiarity determines food acceptance (Hwang & Lin, 2010). Furthermore, starch-based kitchen products can be bought in a supermarket, so people may consider them less like a treatment and may therefore be more likely to accept them.

The aim of this study was to compare the effects of a gum-based clinical thickening agent with two starch-based kitchen products on taste and aroma intensity and texture pleasantness of thickened soup, as perceived by participants with PD and healthy participants.

2. Material and methods:

2.1 Study design

An observational, cross-sectional study was conducted between February 2017 and October 2018 in participants with PD and healthy aged persons. The study consisted of sensory analysis (a paired comparison test) and an odor identification test. Three different thickening agents were evaluated in a broccoli soup, namely the clinical thickener Resource Thicken Up Clear (RTUC) (Nestlé, Switzerland), based on xanthan gum and maltodextrin and two kitchen products, namely potato starch (PS) (Soubry, Belgium), and quinoa flour (QF) (Markal, France). Following secondary outcome measures were also evaluated: a general questionnaire on health and medication use, the Radboud Oral Motor Inventory for Parkinson's Disease (ROMP) questionnaire and the Dysphagia Handicap Index (DHI) questionnaire (Kalf et al., 2011; Silbergleit, Schultz, Jacobson, Beardsley, & Johnson, 2012). The ROMP questionnaire evaluates patient-perceived problems on 2 domains, saliva control and swallowing, whereas the DHI questionnaire assesses the so-called handicapping effect of dysphagia (Kalf et al., 2011; Silbergleit et al., 2012). The study protocol complied with the Helsinki declaration and was approved by the Ethics Committee of the University of Leuven (S61771- B322201837590).

2.2 Study population

Participants with PD and healthy volunteers were recruited in collaboration with the patient's organization 'Parki's Cook Atelier' and regional departments of the patient's organization 'Flemish Parkinson Association'. Inclusion criteria for participants with PD were an age above 55 years old , self-reported diagnosis of PD, cross-checked by the research team. The inclusion criterion for healthy volunteers was an age above 55 years old. People suffering from head and neck cancer were excluded from the study.

2.3 Preparation and characterization of the soups

2.3.1 Selection of food matrix and thickeners

A blended broccoli soup was used since it is a food product that is often consumed by people over the age of 50 and it is often on the menu of care facilities (Donahue, Crowe, & Lawrence, 2015). Furthermore, a blended soup has naturally a thicker consistency than aqueous beverages, so it generally evokes less aversion to the thickened consistency compared to thickened aqueous beverages. The choice for RTUC as reference clinical gum-based thickener was based on the recommendations of speech language therapists regarding patient satisfaction, whom participated in the data collection. Potato starch was included as thickener, since it is one of the most frequently used starches in Belgium. In recent years, the interest in starches of non-conventional sources has grown to obtain added functional properties, including stabilizing or swelling characteristics, combined with added nutritional value (Santana & Meireles, 2014). Quinoa is a non-conventional starch source that received renewed interest over the last few years, because of its nutritional qualities (Li & Zhu, 2018). Furthermore, quinoa starch reportedly has a high freeze-thaw stability, depending on the used variety (Ahamed, Singhal, Kulkarni, & Pal, 1996; Li & Zhu, 2018; Lindeboom, Chang, Falk, & Tyler, 2005). The choice to include quinoa starch was based on the combination of these nutritional and functional qualities.

2.3.2 Preparation of the soups

The basis of the broccoli soup was prepared on pilot-scale, using an industrial cooking kettle (Firex, Italy). After bringing the soup to boiling point, it was homogenized using a colloid mill (Microcut series Stephan, Germany) with a slanted tooth cutting ring of 0.05 mm. The soup was aliquoted into recipients of 500ml or 1000ml and frozen at -20°C until further analyses. For each analysis, three samples of thawed soup were brought to boiling point and thickened with RTUC (0.3g/100ml), PS (0.7g/100ml) or QF (0.75g/100ml). Each soup was thickened and afterwards seasoned with basil and a herb cheese (Philadelphia with Provencal herbs, Mondelez, Switzerland) resulting in nectar thick soup (viscosity between 51 and 350 cP), which corresponded with IDDSI level 2 (Cichero et al., 2017; Felt, 1999). The recipe of the unthickened soup is shown in supplementary table S1. For sensory analysis, a certain amount of soup was thawed in accordance with the number of participants that were registered. Thickened soups were prepared at location as mentioned above and kept at a temperature of 60°C in a bain-marie device (MaxPro Foodwarming Systems, EMGA International B.V., the Netherlands).

2.4 Characterization of the soups

2.4.1 General characterization

The stability during 24h at 4°C of the 3 thickened soups and the unthickened soup as a reference sample was determined through the use of a dispersion stability analyzer (Turbiscan, Formulaction, France). Colorimetric measurements (colorimeter, Konica Minolta, Japan), dry matter determination (moisture analyzer, Mettler Toledo, United States of America), IDDSI Flow test and Bostwick measurements (consistometer, Bostwick, CSC Scientific Company, Inc., United States of America) were carried out on all 4 soups. A nutritional analysis (protein, total fat, fatty acid composition, total carbohydrates, mono- and disaccharides, total dietary fiber, ash, minerals and moisture content) of the unthickened soup was carried out by accredited Laboratorium Ecca, Belgium, results shown in supplementary table S2.

2.4.2 Rheological assessment of the soups

Rheological measurements were carried out following protocol of Kim *et al.* (2014), with some modifications (S. G. Kim, Yoo, & Yoo, 2014). Flow properties and viscoelastic behavior of the soups with 3 different thickening agents and without thickening agent (reference sample) were measured using an Anton Paar rheometer, using a bob and cup geometry for better temperature control. Steady flow data were obtained over a shear rate range of 1 – 100 s^{-1}. Linear viscoelastic region of each soup was determined through amplitude sweeps. Dynamic rheological data were determined through frequency sweeps over the range of 100 to 0.1 rad.s^{-1} at 0.1% strain, in the linear viscoelastic region. Rheological measurements were carried out at 60°C (determined as the serving temperature) and 45°C (determined as the eating temperature). Each soup was measured in triplicate.

2.4.3 Volatile profiling of the soups

The volatile profile was determined using automated headspace solid phase microextraction (HS-SPME) – gas chromatography-mass spectrometry (GC-MS) using a Gerstel MPS sampler coupled to an Agilent 7890A GC and 5975C inert XL mass spectrometer (Agilent, USA) (Mondello et al., 2005). For this, 10ml of each soup (unthickened soup as a reference and all thickened soups) was added to a 20 mL headspace vial and immediately capped. Next the vial was incubated for 30 minutes at 45°C, followed by 30 minutes extraction at the same temperature with a Supelco 50/30µm DVB/CAR/PDMS fiber (Supelco, USA). The SPME fiber was desorbed in splitless mode at 250°C and compounds were separated on a DB-5MS column (30m x 250 µm x 1 µm) using a helium flow rate of 2.5 mL/min. Oven temperature program was set as followed: start at 35°C, hold for 3 minutes, then raised to 290 °C at a rate of 7.5°C and hold for 5 minutes. Mass spectrometer was operated in full scan mode (30 – 350 m/z) using electron impact ionization (EI). As a blank, an empty vial was measured and each soup was analysed in triplicate.

2.4.4 Sensory profile by a trained panel: Free Choice Profiling and Quantitative Descriptive Analysis

Over the course of 3 weeks, sensory training and evaluation were carried out by a trained panel of healthy adults. The panel consisted of 6 men and 15 women, who were all experienced in sensory analysis and able to distinguish both texture and basic taste differences (based upon 10 annual sessions of approximately 30 minutes). During the training sessions, the panel experienced the different sensory profiles of the soups for the first time, got familiar with the different sensory attributes and developed their own glossary to describe them, following the protocol of Zamora *et al*. (2004) (Zamora & Guirao, 2004). Training sessions comprised of Free Choice Profiling (FCP) analyses (Carr, Civille, & Meilgaard, 2007; Zamora & Guirao, 2004). Three separate FCP analyses of approximately 1-1,5 hour were carried out to develop the glossary for flavor, texture and aroma attributes (results not shown). During training, the panel was closely monitored. Evaluation of the 4 soups was carried out through one Quantitative Descriptive Analysis (QDA) session using Fizz acquisition 2.51 software (Biosystèmes, France) (Puri, Khamrui, Khetra, Malhotra, & Devraja, 2016; Stone, Sidel, Oliver, Woolsey, & Singleton, 2008). The panel evaluated the perceived intensity of the attributes, selected during training, individually on a 10cm line scale. All samples had a 3 digit code and were presented in a randomized order. The objective of the QDA was to characterize how the sensory aspects of taste, aroma and texture of the thickened soups differed from the unthickened soup (reference soup) and how these characteristics differed between thickeners.

2.5 Sensory analysis in the study population

2.5.1 Sample size

Based on ISO-norm 5495:2005(E), sample size of the paired comparison analysis was determined at 30 participants with PD and 30 healthy volunteers with a power of 80% and significance level $\alpha=0.05$, where 50% of the population is able to distinguish the soup samples (Pd=50%) (International Organization for Standardization (ISO), 2005).

2.5.2 Sniffin' Sticks

To analyze a potential influence of the participant's sense of smell on the paired comparison analysis results, an odor identification test with the 16-item Sniffin' Sticks (Identification test 16, Blue) was used to evaluate the sense of smell of the participants with or without PD (Besser, Jobs, Liu, Mueller, & Renner, 2018). This test consists of 16 fragrance pens, with everyday scents such as the smell of leather or pineapple. The participant was offered the fragrance pens one by one and had to identify the smell by means of multiple choice (4 options for each fragrance).

2.5.3 Paired comparison analysis

The soups thickened with 3 different thickeners were evaluated by aged people with and without PD. A paired comparison analysis was carried out (International Organization for Standardization (ISO), 2005). During a first series, the PS was compared to RTUC. Each participant received the 2 soups simultaneously and was asked to individually evaluate the soups based on taste, aroma and texture. They had to answer following 3 questions: 'Which soup has the most intense taste?', 'Which soup has the most intense aroma?' and 'Which soup has the most pleasant texture?'. All samples had a 3 digit code. During the second series, QF was compared to RTUC, following the same procedure. All samples only differed in the used thickening agent. This sensory analysis is a forced choice procedure, in which the participant must select an answer (International Organization for Standardization (ISO), 2005).

2.5.4 Secondary outcome measures

The general questionnaire on health and medication intake, the ROMP and DHI questionnaire were completed after sensory analysis tests.

2.6 Data analysis

Differences in color of samples were calculated based on CIELAB ΔE, see Equation 1 (Perez, Saleh, Yebra, & Pulgar, 2007). After data collection from volatile profiling, volatile compounds were identified using Unknown analysis of Masshunter (Agilent, United States of

America (USA)). Identification of volatile compounds was based on both spectral match, compared to both the National Institute of Standards and Technology (NIST)- as an in-house database, and retention index (RI), compared to both the aroma office- (Gerstel) as an in-house database. RI calibration of the chromatogram was done using an alkane standard solution (C8-C20) (Sigma-Aldrich, USA). Results from the QDA were analyzed with Fizz calculations 2.50 (Biosystèmes). Collected data from the Sniffin' sticks was analyzed according to the kit's guidelines, each correctly identified odor obtained a score of 1, with a total score as the sum of all correctly identified odors ranging from 0 to 16. A total score lower than or equal to 8 was defined as anosmia, a score between 8 and 11 was defined as hyposmia, whereas a score above 11 was defined as normosmia (Hummel, Kobal, Gudziol, & Mackay-Sim, 2007). Data from paired comparison analyses were processed according to International Standard ISO 5495:2005(E) (Schlich, 1993).

$$\Delta E = \sqrt{((\Delta L)\hat{}2\ ) + (\Delta a)\hat{}2 + (\Delta b)^2} \qquad \text{(Eq. 1)}$$

2.7 Statistical analysis

Normality of data was assessed using the Shapiro-Wilk test. Possible correlations between categorical data were analyzed using Pearson's Chi Square test, possible correlations between age, sniffin' sticks score, ROMP or DHI and categorical data were analyzed using a Mann-Whitney U test. Potential differences in characterization data, including rheological and aroma profiling data, were analyzed using One way-ANOVA. The sensory profile was analyzed using two way-ANOVA, with attribute and panelist as fixed factors. Post-hoc analysis was done using Tukey's test. Logistic regression was used to analyze possible correlations between participants' characteristics (including diagnosis of PD, age, sniffin' sticks score, gender, health-related complaints, medication intake, potential side effects of medication based on the patient information leaflet and scores of ROMP and DHI) and choice of soup per attribute.

Statistical significance was determined as $p < 0.05$. The data were analyzed with Statistica 13.1, with the exception of the sensory profile that was analyzed with Fizz calculations 2.50.

3. <u>Results</u>

3.1 Characterization of soups

No differences in stability or dry matter content were observed between the reference soup and thickened soups. Colorimetric measurements demonstrated that thickened soups had a different color than the reference soup, but only perceptible through close observation (consistent with a ΔE between 1 and 2). ΔE of RTUC, PS and QF compared to reference soup were 1.6, 1.8 and 1.0 respectively.

The reference soup had a mean Bostwick of 24±0.5cm, whereas the thickened soups had a mean Bostwick of 14.8±0.8cm. A significant difference in Bostwick was observed ($F(3,8)=460$, $p<0.001$, $\eta^2=0.99$). No difference between RTUC (15.0±0.0cm) and QF (15.5±0.0cm) was observed, whereas reference soup, PS (14.0±0.5cm), differed from RTUC, QF and each other. Results of the rheological assessment of the reference soup and thickened soups showed that all samples were pseudoplastic fluids with weak gel-like behavior at both the serving and eating temperature. A significant difference in viscosity at shear rate of $50s^{-1}$ was observed at 45°C ($F(3,8)=932.2$, $p<0.001$, $\eta^2=0.99$) and at 60°C ($F(3,8)=2297.0$, $p<0.001$, $\eta^2=0.99$). All samples were significantly different from each other.

Volatile profiling demonstrated a reduced release of 61.4%, 46.2% and 38.5% of the volatile components compared to the reference soup after thickening with RTUC, PS and QF respectively. Sensory profiling results by the trained panel demonstrated significant differences in general taste intensity ($F(3,83)=4.70$, $p=0.005$, $\eta^2_p=0.19$), vegetable taste ($F(3,83)=3.09$, $p=0.034$, $\eta^2_p=0.13$), general thickness ($F(3,83)=11.33$, $p<0.001$, $\eta^2_p=0.36$), stickiness ($F(3,83)=11.74$, $p<0.001$, $\eta^2_p=0.37$), pudding-like mouthfeel ($F(3,83)=13.17$, $p<0.001$, $\eta^2_p=0.40$) and graininess ($F(3,83)=3.41$, $p=0.023$, $\eta^2_p=0.15$) among the soup samples, see Figure 1. Significant panel variation ($p<0.05$) existed in all attributes, except swallowability. However, no interaction effect of panel and attribute was found. General taste intensity of PS-thickened soup was significantly lower than that of RTUC and the reference soup, whereas post-hoc analysis demonstrated no difference in vegetable taste among the soups.. All thickeners had a higher score for general thickness and stickiness compared to the reference soup, but no significant difference was observed between thickeners. All three thickeners had a more pudding-like mouthfeel than the reference soup, however in the PS-sample the pudding-like mouthfeel was significantly higher compared to the other two thickeners. The PS-soup had a significantly grainier texture compared to the RTUC-sample.

3.2 Study population

A total of 162 participants were recruited in this study and only 7 participants were excluded due to not meeting inclusion criteria. In total 155 participants aged 56-92 years were included in this study, of which 83 participants with PD and 72 healthy controls. In a first paired comparison analysis with PS and RTUC, 36 participants with PD, 20 men and 16 women, and 41 healthy controls, 14 men and 27 women, participated. In the second paired comparison analysis with QF and RTUC, 47 participants with PD, 28 men and 19 women, and 31 healthy controls, 8 men and 23 women, took part in the sensory analysis. Of all participants, 90 completed the Sniffin' Sticks test, namely 54 participants with PDand 36 healthy controls. The 65 participants that did not participate, were unwilling because of reporting fatigue or they claimed to be unable to smell anything. For similar reasons of reporting fatigue, the ROMP and DHI questionnaires were completed by respectively 90 and 94 participants. A detailed overview of study population demographics is shown in Table 1.

3.3 Paired comparison analysis

In the paired comparison analysis with RTUC and PS, taste ($p<0.001$) and aroma ($p<0.05$) of PS-thickened soup were experienced as more intense and texture as more pleasant by more than half of all participants, see Figure 1A, B and C. Both taste ($p<0.01$ in participants with PD, $p<0.05$ in healthy controls) and aroma of the PS-thickened soup were experienced as more intense by the majority of participants with PD and healthy controls (Figure 2A and B). However, a significant difference ($p=0.01$) between participants with PD and healthy controls was observed for soup texture. Texture of PS-thickened soup was preferred by only 37.5% of participants with PD, whereas 71.8% ($p<0.01$) of healthy controls chose the texture of PS-thickened soup over RTUC-thickened soup see Figure 2C. A trend ($p=0.057$) towards an association between older age and choice of soup based on texture was found. No other statistical significant associations between age or gender and paired comparison results of participants with PD were found.

Similar results were found in the paired comparison analysis with RTUC and QF; the majority of participants experienced taste ($p<0.01$) and aroma ($p<0.05$) of QF-thickened soup as more intense and QF texture as more pleasant, see Figure 1D, E and F. No significant differences were found between participants with PD and healthy controls, most participants of both groups chose QF-thickened soup over RTUC-thickened soup for all 3 attributes. Taste ($p<0.05$ in participants with PD) and aroma ($p=0.010$ in participants with PD) and QF-thickened soup was experienced as more intense and texture as more pleasant by the majority of participants with PD and healthy controls. No statistical significant associations between age or gender and paired comparison results of participants with PD were found.

Based on the scores of the ROMP and DHI questionnaires, we determined that none of the participants suffered from severe dysphagia (see Table 1). However, a significant difference was found in mean scores for ROMP ($U=145.5$, $p<0.001$) and DHI ($U=212.5$, $p<0.001$) between participants with PD, respectively 25.1±8.4 and 15.8±14.8, and healthy controls, respectively 17.1±2.9 and 4±11.4. No effect of either ROMP- or DHI-scores on paired comparison analyses results was found. Our medication intake results showed that participants with PDhad a significant higher intake ($\chi^2(1, N=152)=39.59$, $p<0.001$) of medication with development of dry mouth (xerostomia) as a potential side effect, see Table 1. Although having a dry mouth can complicate the swallowing process, we found no statistical relevant effects of either medication intake or potential side effects of medication on the results of the paired comparison analyses.

Sniffin' sticks test results demonstrated that 75.9% of participants with PD suffered from anosmia, 16.7% had hyposmia and only 7.4% had a normal sense of smell. In contrast, 22.2% of healthy volunteers had anosmia, 38.9% had hyposmia and 38.9% had normosmia. Difference in sense of smell was significant between participants with PD and healthy volunteers ($U=166.0$, $p<0.001$). No effect of gender or age on Sniffin' sticks score was found. Sniffin' sticks score had no influence on paired comparison analyses.

4. Discussion

According to the authors' knowledge, this is the first study that assessed participants with PD's perception of texture pleasantness, taste and aroma intensity of different thickeners. Participants with PD and healthy volunteers both considered the taste and aroma of starch-based thickened soups to be more intense than of gum-thickened soup. Texture pleasantness of starch-based thickened soups was preferred, although not statistically significant, by more than half of participants, with the only exception that participants with PD preferred the texture of RTUC-thickened soup compared to PS-thickened soup. Although none of the participants with PD suffered from severe dysphagia, we cannot exclude the possibility that participants with PD were familiar with RTUC-texture, because of previous prescriptions of TMF. Furthermore, RTUC contains a certain amount of maltodextrin, which may influence the evaluated sensory properties of the thickened soups that we cannot account for.

It is important to acknowledge that no participants with PD suffering from severe dysphagia were included in this study, therefore no claims regarding safety of the tested thickening agents can be made. Based on our results, the use of QF seems worthwhile to further explore in the development of dysphagia food products.

The shear-thinning, weak gel-like behavior of gum-based thickened soup is similar to results of previous studies (S. G. Kim et al., 2014). Mackley *et al.* (2013) reported similar rheological shear-thinning, weak gel-like behavior of a cornstarch thickener as observed in PS- and QF-thickened soups (Mackley et al., 2013). Furthermore, the same rheological behavior was demonstrated in Tarhana soup with different concentrations of QF (Demir, Kutlu, & Yilmaz, 2017). Although starch- and gum-based thickeners have differences in sensory attributes of texture and mouthfeel, their rheological behavior is similar at IDDSI level 2. These results suggest that although the soup's viscoelastic behavior is important during swallowing, it seems not representative of texture and mouthfeel. The measured viscosities of the thickened soups at shear rate of $50 s^{-1}$ were, although similar, significantly different. However, based on the sensory profile, the perceived general thickness did not differ between the thickened soups.

The observed panel variation in the sensory profile is often observed in descriptive analysis, probably because of a non-uniform use of the line scale (Ickes & Cadwallader, 2017). However, the lack of interaction effects between attributes and panel indicates that the panel agreed on the ranking order of attribute intensity.

Wendin *et al.* (2010) reported that a trained panel judged thickened soups easier to swallow compared to unthickened soup, whereas no difference in swallowability was found in our study (Wendin et al., 2010). Similar to our results, Matta *et al.* (2006) reported that a trained panel found starch-thickened juice to be grainier compared to gum-based thickened juice (Matta et al., 2006). They compared starch-based thickeners Thick & Easy and Thicken Up (based on modified maize and cornstarch respectively) with gum-based thickeners Thick & Clear (based on cellulose gum) and Simply Thick (a gel based on xanthan gum). Their results demonstrated that all thickeners suppressed the beverages' main flavors, whereas our panel found no significant difference in general taste intensity between the reference and RTUC-thickened soup (Matta et al., 2006). However, our results also demonstrated a suppression of vegetable taste in RTUC-thickened soup, whereas there was no difference in vegetable taste between QF-thickened soup and the reference soup. These results suggest that taste suppression due to thickening depends on thickener composition and the tested liquid. Depending on their composition, different interactions between thickeners and flavor compounds present in the tested liquid can occur (Gallardo-Escamilla, Kelly, & Delahunty, 2007). Ong *et al.* (2018) demonstrated that different IDDSI levels can be distinguished based on different sensory characteristics, but also within one IDDSI level sensory differences can be identified based on thickener type and the liquid being thickened (Ong, Steele, & Duizer, 2018).

Macqueen *et al.* (2003) evaluated the preference of aged persons with dysphagia of 5 commercial thickeners, using visual analog scales (Macqueen, Taubert, Cotter, Stevens, & Frost, 2003). All thickeners were modified starches, however a small but significant difference in palatability between the 5 thickeners was found (Macqueen et al., 2003). Their results demonstrated that Nutilis and Thixo D were preferred above Thick & Easy by aged patients with dysphagia (Macqueen et al., 2003). Horwarth *et al.* (2005) investigated whether natural thickeners, e.g. chocolate pudding and pie filling to thicken hot chocolate, were preferred over commercial thickeners, a gum- and a starch-based thickener, by healthy adults (Horwarth, Ball, & Smith, 2005). In contrast to our results, both natural and gum-based thickener were preferred over the starch-based thickener in hot chocolate (Horwarth et al., 2005). It seems, however, that sweet thickened beverages are better accepted (Horwarth et al., 2005; Yver, Kennedy, & Mirza, 2018). Similar to our results, Ferry *et al.* (2006) demonstrated that HPMC reduces saltiness and basil flavor more, compared to 3 types of starch (Ferry et al., 2006). Flavor reduction in thickened systems can be associated with increased viscosity, that potentially limits flavor compounds diffusion (Guichard, 2002). However, the thickeners in this study were tested at similar viscosities, indicating that thickener type influences flavor release. This is consistent with previous studies (Arancibia et al., 2015; Ferry et al., 2006). It has been suggested that xanthan gums interacts with flavor compounds through hydrophobic binding (Bylaite et al., 2005). Interactions between starch and flavor compounds have been attributed to amylose flavor complexation or hydrogen bonding (Guichard, 2002). Differences in taste retention or mouthfeel between PS and QF could be explained by their structural differences. Quinoa starch has extremely small granules (0.3 – 2μm) and A-type polymorph crystallinity, whereas potato starch has large granules (30-100μm) and B-type polymorph crystallinity (Abdul Hadi, Wiege, Stabenau, Marefati, & Rayner, 2020; Kong, Lee, Kim, & Ziegler, 2014).

Further sensory testing of different thickeners in different matrices for patient populations with a high risk of dysphagia should be done to ensure, patients receive the most suitable products according to their sensory needs. An acceptance of 75% should be met to consider sensory properties of the thickened liquid to be accepted (Carr et al., 2007; Vieira et al., 2018). Although paired comparison analyses demonstrated higher taste/aroma intensity and texture pleasantness of both starch-based thickeners, results of volatile and sensory profiling demonstrated reduced taste and volatile compounds in all thickened soups. Thus, further research on flavor enhancement of thickened beverages and its use in different patient populations is clearly needed, to provide patients more personalized recommendations.

Besides sensory characteristics and safe swallowing, other effects of thickeners should be taken into consideration when recommending them. Participants with PD often suffer from delayed gastric emptying, which may result in nausea, abdominal bloating and loss of appetite (Marrinan, Emmanuel, & Burn, 2014). It has been suggested that xanthan gum delays gastric emptying (Gidley, 2013; Vera C, Laguna, Zura, Puente, & Muñoz, 2019; Zhang, Zhang, & Vardhanabhuti, 2014), which may worsen gastrointestinal symptoms inherent to PD and result in reduced food intake.

Cecchini *et al.* (2019) reported similar scores for the Sniffin' sticks identification test to our results in participants with PD (7.0±3.3 vs 6.3±3.2) and healthy volunteers (10.6±2.6 vs 10.2±2.3) (Cecchini et al., 2019). They combined olfactory testing with taste evaluation through the Whole Mouth test and Taste Strips test (Cecchini et al., 2019; Landis et al., 2009; Mueller et al., 2003). Their results demonstrated no correlation between olfaction and taste scores, which is consistent with our results (Cecchini et al., 2019). Gustatory and olfactory testing in people with PD may demonstrate which flavors are better perceived compared to others, on which future personalized recommendations regarding flavor enhancement could be based.

The current study has some limitations. Participants in this study were recruited through communication via patient organizations, Flemish Parkinson Association and Parki's Cook Atelier. This recruiting strategy includes potential bias, since the healthy volunteers and participants with PD willing to participate, may have been characterized by a greater interest in food and health. Although sample size was determined based on ISO 5495 protocol, it was still relatively small, resulting in a restricted external validity. Nutritional status of participants could have a potential effect on their sensory perception, however nutritional status was not used as an inclusion criterion. Nonetheless, this study still provides useful information regarding thickener preference in participants with PD. The results of the study population, however, could not be compared to the sensory profile of the soups developed by a trained panel, because of the difference in methodology. FCP and QDA are not applicable in an aged population, because of the large number of samples and the difficulty of the test itself. Therefore, a paired comparison sensory analysis was chosen. This sensory analysis has a maximum of two test samples, to avoid reporting fatigue of the panel, while it has still sufficient statistical power.

5. Conclusion

This study, the first in Belgian participants with PD, demonstrates that kitchen products demonstrated higher taste and aroma intensity for the majority of the target population to thicken soups. Although we did not analyze acceptance of the products in this study, we assume that increased perceived taste/aroma intensity and improved texture pleasantness will result in higher acceptance. So further research regarding effects of taste and/or aroma boosters combined with thickeners is needed to improve palatability of thickened liquids and reach an acceptance of minimum 75%.

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Statement of authorship

G.V. and F.B. developed the study design. A.B provided feedback on study design and assisted in data collection. F.B. analyzed obtained data. S.V.W. assisted in statistical analysis. F.B., C.M. and G.V. drafted the manuscript and all authors commented on and approved the final manuscript. All authors are in agreement with the manuscript and declare that the content has not been published elsewhere.

Declaration of interest

None.

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Table 1 Overview of participants' characteristics

	Participants with PD (n=83)	**Healthy volunteers (n=72)**	**P - value**
Gender			
Men/women	48/35	22/50	0.0007
Age			
Age (years), mean±SD	67.7±7.3	72.9±9.6	0.002
Duration of disease (years), mean±SD	11.1±6.8	-	
Duration of disease (years), minimum - maximum	0.2 - 27	-	
Medication intake			
Antibiotics (n)	3	1	0.38
Antidepressants (n)	13	4	0.04
Medication for high blood pressure (n)	24	26	0.35
Medication for high cholesterol levels (n)	19	29	0.02
Anti-inflammatory drugs (n)	10	8	0.84
Parkinson's medication (n)	70	-	-
Levodopa + DOPA decarboxylase inhibitor (n)	62	-	-
Dopamine agonists (n)	41	-	-
Monoamino-oxidase B inhibitor (n)	34	-	-
Amantadine (n)	4	-	-
Potential side effects of medication intake*			
Gustatory side effects (n)	8	3	0.18
Dry mouth (n)	41	3	0.000001
ROMP questionnaire	**Participants with PD (n=54)**	**Healthy volunteers (n=36)**	
ROMP (score, min. 16; max. 80), mean±SD	25.1±8.4	17.1±2.9	0.004
ROMP (score, min. 16; max. 80), minimum-maximum	16-47	16-28	
DHI questionnaire	**Participants with PD (n=57)**	**Healthy volunteers (n=37)**	
DHI (score, min. 0; max. 100), mean±SD	15.8±14.8	4±11.4	0.001
DHI (score, min. 0; max. 100), minimum-maximum	0-74	0-50	

*SD; standard deviation, n; number of participants, ROMP; Radboud Oral Motor Inventory for Parkinson's Disease, DHI; Dysphagia Handicap Index *; based on the patient information leaflet*

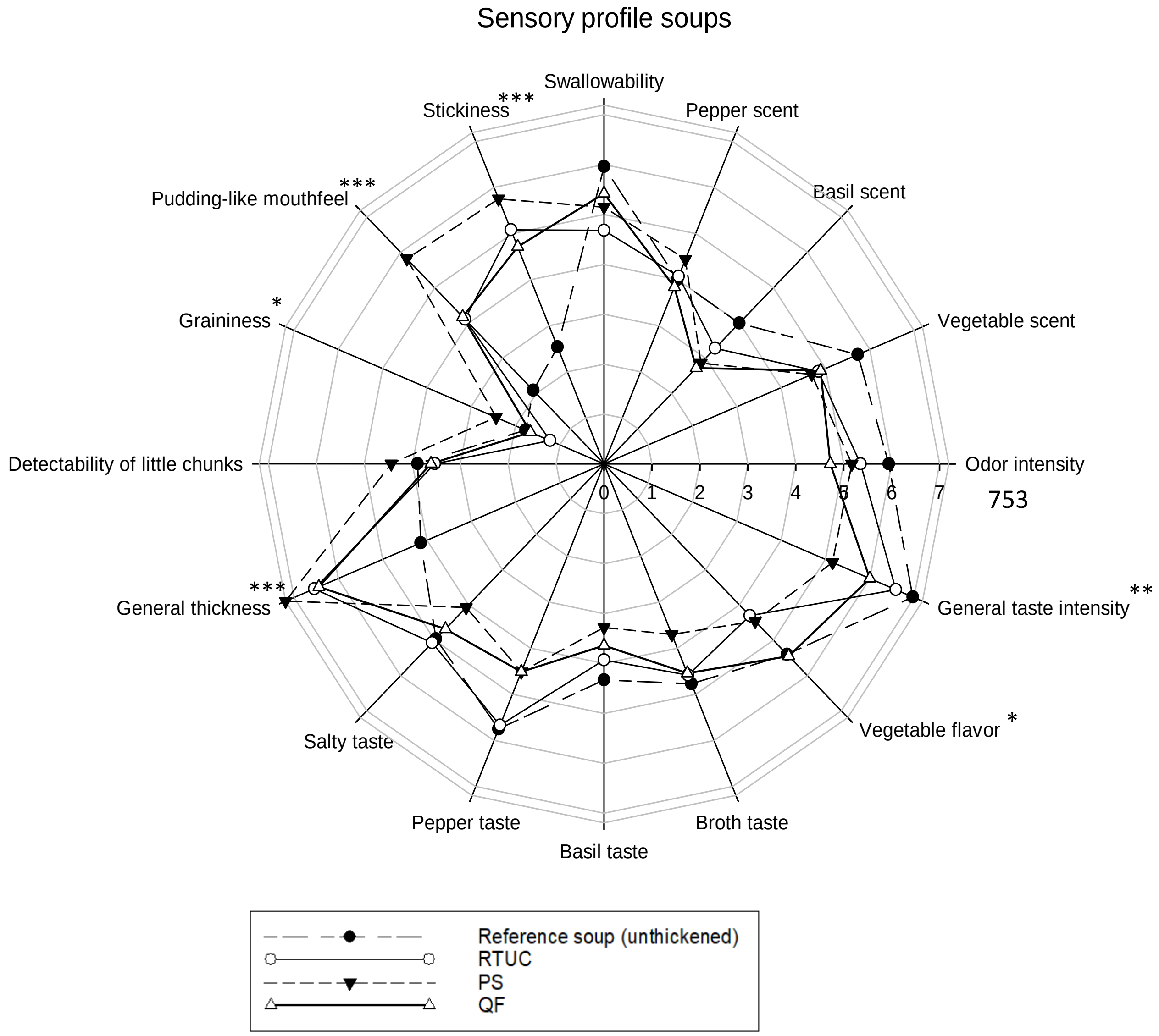

*Figure 1 Sensory profile of different soup samples based on quantitative descriptive analysis by a trained panel, RTUC, Resource Thicken Up Clear, PS; Potato starch, QF; Quinoa flour, significance level p<0.05; *, p<0.01;**, p<0.001;****

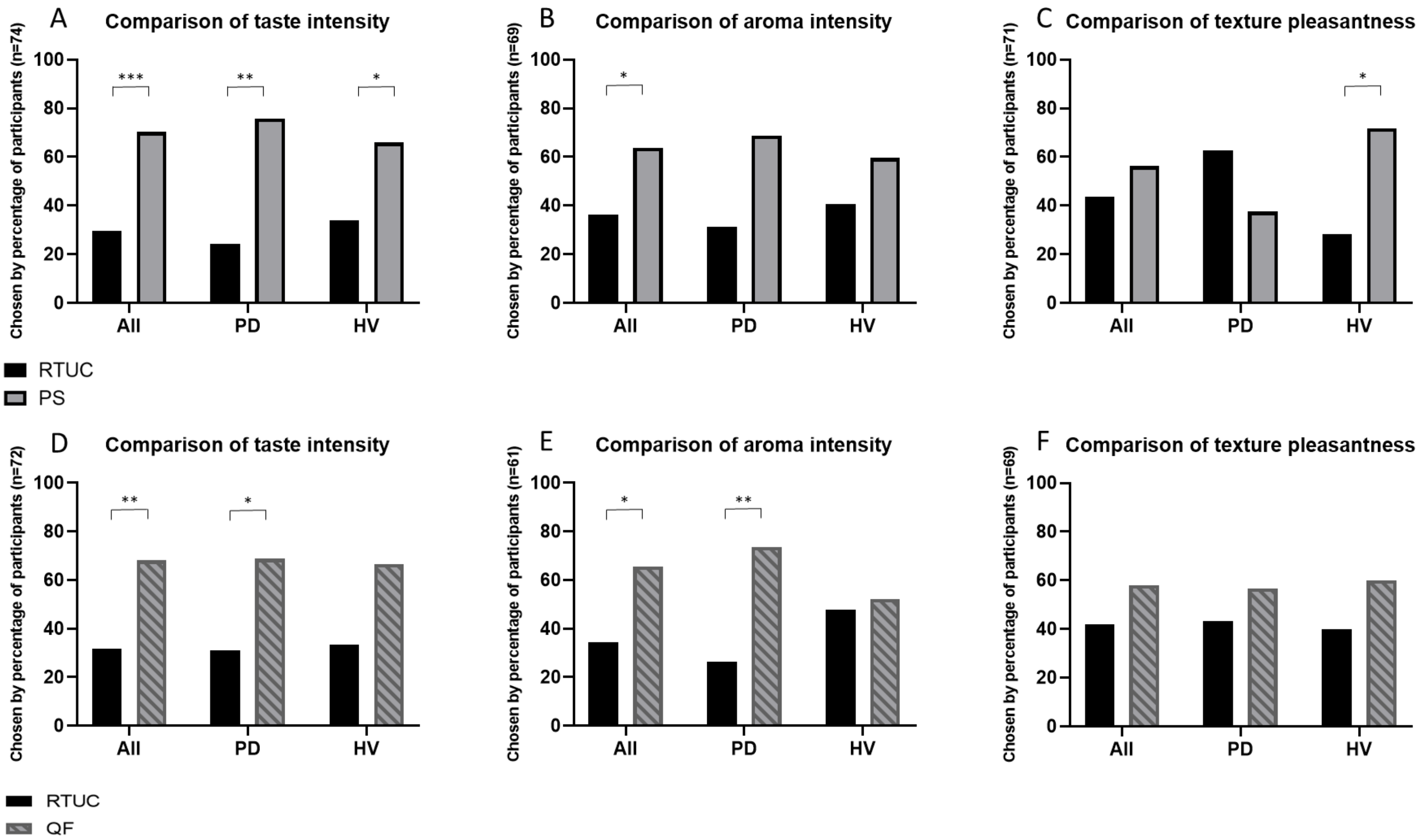

*Figure 2 Results of paired comparison analyses, PD; participants with Parkinson's Disease,, HV; Healthy volunteers, RTUC; Resource Thicken Up Clear, PS; potato starch, QF; quinoa flour, significance level p<0.05; *, p<0.01;**, p<0.001;****