Institutionalized Elderly are able to Detect Small Viscosity Variations in Thickened Water with Gum-based Thickeners. Should Texture Classifications be Reviewed?

Fernando Calmarza-Chueca
Department of Endocrinology and Nutrition, Miguel Servet Hospital, Zaragoza, Spain

Ana-Cristina Sánchez-Gimeno
Senior Lecturer in Food Technology. Faculty of Veterinary, Zaragoza, Spain

Javier Perez-Nogueras
Geriatric Unit, Elias Martinez Nursing Home, Zaragoza, Spain

Alberto Caverni-Muñoz
Diet Service. Renal patients association. Alcer Ebro, Zaragoza, Spain

Alejandro Sanz-Arque
Aragón Health Research Institute, Zaragoza, Spain

José Miguel Arbones-Mainar
Adipocyte and Fat Biology Laboratory (AdipoFat), Translational Research Unit, University Hospital Miguel Servet, Instituto Aragones de Ciencias de la Salud (IACS), 50009 Zaragoza, Spain

Alejandro Sanz-Paris (sanzparisalejandro@gmail.com)
Department of Endocrinology and Nutrition, Miguel Servet Hospital, Zaragoza, Spain

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Research Article

Keywords: Deglutition Disorders, Dysphagia, institutionalized elderly population, Rheology, Sensory analysis, Gum-based thickener, Viscosity

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Article

Institutionalized elderly are able to detect small viscosity variations in thickened water with gum-based thickeners. Should texture classifications be reviewed?

Fernando Calmarza-Chueca[1], Ana Cristina-Sánchez-Gimeno[2], Javier Perez-Nogueras[3], Alberto Caverni-Muñoz[4], Alejandro Sanz-Arque[5], José Miguel Arbones-Mainar[5,6,7,] Alejandro Sanz-Paris[1,5*]

[1]*Department of Endocrinology and Nutrition, Miguel Servet Hospital, Zaragoza, Spain*

[2]*Senior Lecturer in Food Technology. Faculty of Veterinary, Zaragoza, Spain*

[3]*Geriatric Unit, Elias Martinez Nursing Home, Zaragoza, Spain*

[4]*Diet Service. Renal patients association. Alcer Ebro, Zaragoza, Spain*

[5]*Aragón Health Research Institute, Zaragoza, Spain*

[6]*Adipocyte and Fat Biology Laboratory (AdipoFat), Translational Research Unit, University Hospital Miguel Servet, Instituto Aragones de Ciencias de la Salud (IACS), 50009 Zaragoza, Spain*

[7]*Center for Biomedical Research in Network Physiopathology Obesity and Nutrition (CIBERObn), Institute of Health Carlos III (ISCIII), Madrid, Spain*

**Corresponding author:* asanzp@salud.aragon.es

Abstract:

Background: The prevalence of dysphagia is very high in institutionalized elderly. Knowledge of the rheological and sensory characteristics of the various thickeners is limited, although it has been seen that there are differences between the rheological behaviors of different gum-based thickeners with different composition. We have not found sensory studies of viscosity in institutionalized elderly. Our hypothesis was that viscosity ranges established by the scientific societies seem to be very wide and individuals might be able to detect small differences within the same texture range. The objectives of our study were comparing the rheological characteristics of two commercial gum-based thickeners with different composition, dissolved in water under standard conditions, and checking whether it could be possible to detect different viscosities within the same texture (nectar and honey) with the use of sensory analysis (both with adults and elderly).

Methods: Two commercial thickeners based on gums (NC and RC) were studied analyzing their viscosity in water with different concentrations (shear rate: 50 s^{-1}; temperature: 22-25°C). A sensory analysis involving 26 elderly and 29 adult controls was carried out to evaluate whether differences within nectar and honey textures among gum-based thickeners could be distinguished.

Results: As the shear rate increases, viscosity decreases (non-Newtonian and pseudoplastic behavior). At the same concentration, each thickener produces a different viscosity ($p<0.05$). Institutionalized elderly detected viscosity differences in nectar range of 49.9 (2.5) mPa·s ($p<0.05$) y 102.2 (4.7) mPa·s ($p<0.0001$). They also detected viscosity differences in honey texture range of 134.6 (9.7) mPa·s ($p<0.05$) y 199,3 (9,2) mPa·s ($p<0.0001$). Their caregivers also detected viscosity differences in both viscosity ranges ($p<0.0001$).

Conclusions: Our results suggest that the accepted viscosity ranges for the different textures might be too wide because institutionalized elderly and their caregivers are able to discern small differences in viscosity in nectar and honey textures. Gum-based thickeners with different composition showed differences in viscosity capacity, so they are not interchangeable.

Key Words: Deglutition Disorders; Dysphagia; institutionalized elderly population; Rheology; Sensory analysis; Gum-based thickener; Viscosity

Clinical Relevance Statement

In this work we observed that at the same concentration, each gum-based thickener produces a different viscosity that even elderly people are capable of discriminating. This suggests that the viscosity ranges accepted by most scientific societies for different textures could be too wide. The viscosity of two gum-based thickeners commonly used in clinical practice with water as a solvent varies, depending on their composition and concentration. These facts can be used to optimize the prescription of each thickener. Thickeners are not interchangeable with each other even if they belong to the same group (gum-based thickeners).

67 **Background**

68 Dysphagia is a very frequent clinical symptom in the elderly population and in patients
69 with pathologies such as neurodegenerative diseases, dementia, stroke or some types of
70 cancer. It is estimated that it affects between 15% and 70% in institutionalized elderly
71 [1].There is a variability of the percentage depending on the country where this
72 population is found since there are differences in lifestyle [2]. From the
73 pathophysiological point of view, dysphagia occurs mainly because of obstructive
74 lesions or motor disorders [3] Dysphagia can have very important clinical consequences
75 including aspiration pneumonia, malnutrition, dehydration, and even psychological
76 problems. In many patients with dysphagia, thickening powders are added to the liquids
77 they ingest in order to increase their consistency and viscosity, decrease the flow rate
78 of the bolus during swallowing and prevent its passage into the airway [4]. However,
79 the optimal viscosity of the bolus, which ensures optimal swallowing, has not been
80 optimally established according to the type of dysphagia or its severity [4].

81 On the other hand, rheology is a discipline that studies the deformation of materials in
82 response to external forces, and allows for the determination of material properties such
83 as elasticity and viscosity. In the field of nutrition, it is important to determine the
84 rheological characteristics of the alimentary bolus because they condition to a great
85 extent the swallowing process [4]. There is clinical evidence suggesting that an increase
86 in the viscosity of the alimentary bolus reduces the risk of aspiration [4]. In this sense,
87 the National Dysphagia Diet Task Force [5] defined four levels of thickened liquids
88 that are frequently used in clinical practice. The classification and ranges are based on
89 shear viscosities measured at one single shear rate of 50 s^{-1} and at a temperature of
90 25°C. In this sense, they proposed four consistency levels: 1) Thin for viscosities lower
91 than 50 mPa·s; 2) Nectar-like for viscosities in the range of 51-350 mPa·s; 3) Honey-

like for viscosities in the range of 351-1750 mPa·s; and 4) Spoon-thick or pudding for viscosities above 1750 mPa·s.

For the various commercial thickeners distinct concentrations of product are recommended to reach the nectar, honey or pudding texture, however, as their composition is different, their rheological properties would be different. Comparative data on the rheological properties of the different commercial gum-based thickeners are scarce [6]. Currently, there are very few works comparing the rheological results with the sensory results in thickeners [7] and none where a sensory test involving institutionalized elderly people with commercial thickeners for clinical use was performed. Our hypothesis was that viscosity ranges established by the scientific societies seem to be very wide and individuals, both old and young, might be able to detect small differences within the same texture.

The aims of this work were: 1) Compare the rheological characteristics of two commercial gum-based thickeners with different composition, dissolved in water and under standard conditions; 2) Check with the use of sensory analysis (both with adults and elderly) whether it is possible to detect different viscosities within the same texture (nectar and honey).

2. Methods and analysis

2.1. Thickeners

Two types of commercial thickeners were used, whose composition is shown in Table 1. We used two third generation thickeners (NC and RC) with different types of gums and do not contain starch. The main ingredients of each one of the thickeners are the followings: 1) NC: maltodextrins, guar gum, xanthan gum, potassium chloride and sodium chloride; 2) RC: maltodextrins, xanthan gum, sodium chloride and potassium chloride.

117 **Table 1.** Commercial name and nutritional values of thickeners used in the study.

Composition per 100 g of the product	Thickener NC	Thickener RC
Commercial name	Nutilis clear®	Resource thickener clear®
Kcal	290 kcal	306 kcal
Protein	0.8 g	1 g
Fat	0 g	0 g
Carbohydrates	57.6 g	62 g
Sugar	3.7 g	1.8 g
Fiber	28 g	27 g
Sal	3.8 g	2.7 g
Na	1500 mg	1060 mg
K	<40 mg	400 mg

118

119 *2.2. Solvent*

120 The thickeners were dissolved in commercial mineral water from the Sacalm spring in
121 Sant Hilari (Girona, Spain). This water is sold under the commercial name of
122 Fontvella® and has the following composition: calcium 43.2 mg/l, magnesium 11.5
123 mg/l, sodium 12.3 mg/l, bicarbonates 167 mg/l. It also has a conductivity of 303 µS/m.

124 *2.3. Preparation of the samples*

125 Water and thickeners were mixed in a shaker specially made for use in this study, 16
126 cm high, 22 cm in diameter and with 400 ml capacity. A Nahita Blue Series 5173
127 electronic precision weighing scale was used to weigh the samples. The technique for
128 the preparation of the samples consisted of agitating the shaker 15 times with an
129 approximate arch of 50 cm, intending to reproduce the real conditions of preparation as
130 accurate as possible.

131 The concentrations used for the preparation of the samples in water were between a
132 minimum recommended for a thickener with nectar texture (1.2%) to a maximum
133 recommended for a thickener with pudding texture (4.5%). The manufacturer's
134 recommendations are not very objective measurements ("ladles"), which imply a high
135 degree of subjectivity. In addition, intermediate concentrations, as well as very high
136 (9%) and a very low concentration (0.5%) were added in order to obtain a
137 concentration/viscosity curve as accurate as possible. In this way, the viscosity of the
138 2 gum-based thickeners could be compared with the same concentration values. All the
139 concentrations tested are shown in Table 2.
140
141 **Table 2.** Concentrations of gum-based thickeners made with water.

Samples	Concentration of the thickener (%)											
NC	0.5%	1.2%	**1.5%**	2%	2.4%	**3%**	3.6%	4%	**4.5%**	5.75%	6.9%	9%
RC	0.5%	**1.2%**	1.5%	2%	**2.4%**	3%	**3.6%**	4%	4.5%	5.75%	6.9%	9%

142 * The manufacturer's recommendations for obtaining the different textures are shown in blue for nectar,
143 green for honey, the red for pudding.
144
145 All the formulations were prepared in 200 ml of water, were produced in triplicate and
146 placed in a 200 ml beaker after preparation. Following preparation, the samples were
147 left to rest for 10 minutes before their subsequent analysis.
148
149
150 *2.4. Rheological analysis*
151 A stress-controlled rheometer (MCR 301, Anton Paar Physica, Austria) was employed
152 using a CC17 coaxial cylinder geometry.

153 In order to assess the rheological behavior of the thickened liquids as a function of the
154 shear rate, flow curves were drawn with a range between 0.01 and 200 s^{-1}, plotting the
155 shear stress and viscosity against the shear rate. Viscosity was determined at a shear
156 rate of 50 s^{-1} obtained from each concentration's flow curve. The temperature of the
157 samples varied between 22ºC and 25ºC, trying to emulate the most common
158 temperature conditions during home and clinical consumption [8]. Three specimens of
159 each sample were measured for each determination. Rheological measurements were
160 calculated after 10 minutes of sample preparation. We compared the average viscosity
161 of two thickeners based on gum (NC vs RC) at 50 s^{-1}.
162
163 *2.5. Sensory analysis*
164 Four triangular sensory tests were performed, evaluating the ability to recognize
165 differences between nectar and honey texture, using only commercial gum-based
166 thickeners (both RC and NC) [9]. The analyses were carried out individually with the
167 participants of both panels (see below) seated. A tasting room was set up in the nursing
168 home with four chairs and four tables separated by screens. Prior to the test, the
169 methodology of the sensory test was explained. Two different types of panelists were
170 selected: 1) Panel A: formed by 29 people under 65 years old (22 were women and 7
171 men), all of them health professionals from a nursing home. The average age of this
172 panel was 36 years old. 2) Panel B: formed by 26 people over 65 years old
173 institutionalized in same the residence (14 women and 12 men) with cognitive
174 capacities in good condition and without pathologies that could affect the tasting result.
175 The average age of this panel was 81 years old. First, the thickeners were compared
176 using the concentrations recommended by the manufacturer for nectar texture (test 1)
177 and honey texture (test 3). In addition, two other tests were performed at the same

concentration with the two thickeners for nectar texture (test 2) and honey texture (test 4). Table 3 shows the concentration and viscosity of each of the samples in the 4 triangular sensory tests.

Table 3. Viscosity and concentration of thickeners compared in the triangular tests.

Texture	Sample 1	Sample 2	Sample 3
Test 1 (Nectar)	233.9 (4) mPa·s (NC 1.5%)	131.7 (7) mPa·s (RC 1.2%)	131.7 (7) mPa·s (RC 1.2%)
Test 2 (Nectar)	233.9 (4) mPa·s (NC 1.5%)	183.9 (1) mPa·s (RC 1.5%)	183.9 (1) mPa·s (RC 1.5%)
Test 3 (Honey)	491.3 (1) mPa·s (NC 3%)	292.0 (3) mPa·s (RC 2.4%)	292.0 (3) mPa·s (RC 2.4%)
Test 4 (Honey)	491.3 (1) mPa·s (NC 3%)	356.6 (6) mPa·s (RC 3%)	356.6 (6) mPa·s (RC 3%)

*Viscosity was presented in means (SD standard deviations) and concentration of thickeners in brackets grams of thickener per 100 ml of water.

For each test, three 50 ml opaque chalices containing two similar RC samples and one different NC sample were presented on a plate, all of them coded. Each panelist had to single out the different sample. The samples were presented in white plastic cups. Both panels performed all the tests.

2.6. Ethical aspects

The study was approved by the local ethics committee (Research Ethics Committee of the Autonomous Community of Aragon: CEICA) (registration number C.P.-C.I.

194 PI15/0331). All participants signed an informed consent form before participating in
195 the study. All methods were carried out in accordance with relevant guidelines and
196 regulations.

197 *2.7. Statistical analysis*

198 The statistical software IBM® SPSS® Statistics 25 was used. Quantitative variables
199 were described by means (SD standard deviations), and qualitative variables by means
200 of proportions. It was considered that no variable followed the normal distribution since
201 the number of determinations was 3. Differences were considered significant with a
202 $p<0.05$.

203 Means were compared using the non-parametric Kruskal Wallis and Mann-Whitney U
204 tests.

205 The sensory tests were evaluated according to the significance tables of the UNE-ISO
206 6658 standard [9]. The comparison between the proportions of participants who
207 discriminated or not the textures in the sensory tests were made by means of Chi^2 test.

208

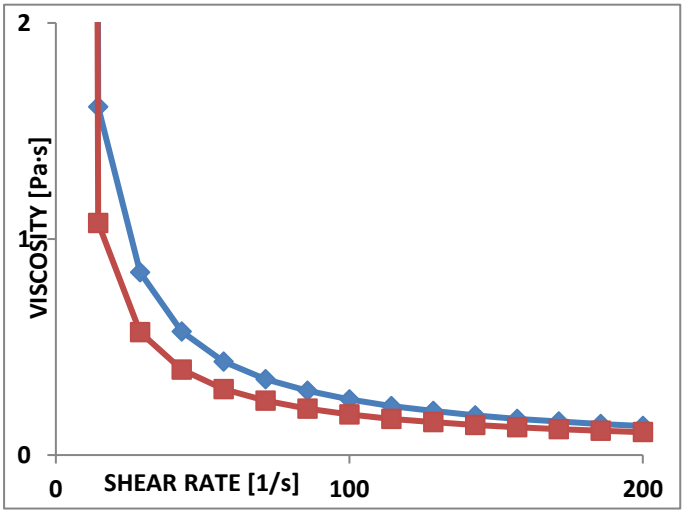
209 **3. Results**

210 *3.1. Viscosity curves of thickeners in water*

211 The results obtained when drawing the viscosity versus shear rate curves with a
212 concentration of 3% for the two gum-based thickeners are shown in Figure 1. These
213 curves show that the viscosity of the thickeners under study decreased with the shear
214 rate, indicating non-Newtonian and pseudoplastic behavior. At low shear rates (0.0998
215 s^{-1}), the viscosity was 84300 mPa·s for NC and 68990 mPa·s for RC. When the shearing
216 speed approached 20 s^{-1}, the viscosity dropped considerably: to 820 mPa·s for NC and
217 580 mPa·s for RC. At 50 s^{-1}, the viscosity dropped even further: to 491 mPa·s for NC
218 and 356 mPa·s for RC. When the shearing speed reached the maximum of our

measurement (200 s^{-1}) the viscosities of all were close to zero. The decrease in viscosity observed as the shear rate increased indicated that the preparations behaved as non-Newtonian fluids, following a pseudoplastic behavior. Figure 1 shows the viscosity curves of the two thickeners at progressively higher shear rates.

Figure 1. Graphical representation of the viscosity curve with the shear rate at a concentration of 3%.



* The purple line corresponds to the red to RC and the blue to NC.

3.2. Viscosity of thickeners at a shear rate of 50 s^{-1}

The average viscosity achieved by each type of thickener at a shear rate of 50 s^{-1} with different concentrations is shown in Table 4. These data were obtained from the flow curves.

241 **Table 4.** Viscosity comparison between gum-based thickeners at a 50 s^{-1} shear rate in

242 different concentrations.

Tested concentrations	**Viscosity of NC** (mean (SD) mPa·s)	**Viscosity of RC** (mean (SD) mPa·s)	*Differences (SD)(*mPa·s) NC vs. RC
0.5%	34.2 (2.4)	**37.9 (1.6)**	*-3.7 (1.7)*
1.2%	**169.6 (8.5)**	131.7 (7.1)	*37.9* [b] *(6.4)*
1.5%	**233.9 (4.1)**	183.9 (1)	*49.9* [d] *(2.5)*
2%	**327.18 (25.1)**	247.3 (5.3)	*79.8* [a] *(14.8)*
2.4%	**352.3 (23.5)**	292 (3.4)	*60.2* [a] *(13.7)*
3%	**491.3 (15.5)**	356.6 (6.2)	*134.6* [d] *(9.7)*
3.6%	**599 (14.4)**	441.6 (8.4)	*157.3* [d] *(9.6)*
4%	**736.28 (27.1)**	450.1 (6.16)	*286.1* [d] *(16.1)*
4.5%	**755.5 (18.7)**	539.9 (22.6)	*215.5* [d] *(16.9)*
5.75%	**1020 (49.2)**	669.6 (17)	*350.4* [d] *(30.1)*
6.9%	**1184.4 (27.5)**	843.3 (75.9)	*341.1* [b] *(46.6)*
9%	**1559.5 (24.2)**	1168.4 (62.6)	*391.0* [c] *(38.7)*

243 *Viscosity was presented in mean (Standard Deviation)
244 * The manufacturer's recommendations for obtaining the different textures are shown in blue for
245 nectar, green for honey, the red for pudding.
246 *In bold: Higher viscosity values obtained between the different concentrations of NC and RC
247 thickeners.
248 *In italics: Average differences.
249 *Significance level: a= $p<0.05$, b= $p<0.01$, c=$p<0.001$ and d= $p<0.0001$.
250
251

252 With the same concentration of thickener, each of them presented a different viscosity

253 at 50 s^{-1}. NC reached a higher viscosity than RC in all concentrations ($p<0.05$), except

254 with the concentration of 0.5%. The dispersion values reflected in the standard

deviation of the means obtained in the three repeated samples of the same concentration were higher with elevated concentrations.

3.3 Sensory Analysis

Table 3 shows the concentrations and viscosities of each sample evaluated by the different sensory analysis tests.

Sensory Test 1 compared two viscosities in the nectar texture range by analyzing one NC and two RC samples with the concentration recommended by the manufacturer for nectar texture (NC 1.5% with a mean (SD) viscosity of 233.9 (4) mPa·s and RC 1.2% with a viscosity of 131.7 (7) mPa·s). In this test, 26 out of 29 panel A tasters (young adults) detected the most viscous sample (89.6%) ($p<0.0001$) and 22 out of 26 panel B tasters (elderly) detected the most viscous sample (84.6%) ($p<0.0001$). Elderly and young participants discriminated among the samples in a very similar way (89.6% vs 84.6%, $p= 0.69$).

Sensory Test 2 again compared two viscosities in the nectar texture range but with the same concentration, one sample of 1.5% NC with a mean (SD) viscosity of 233.9 (4) mPa·s (nectar texture) and two samples of RC with the same concentration (1.5% with a viscosity of 183.9 (1) mPa·s). Of the 29 members of Panel A (young adults), 21 detected which sample was different (72.4%) ($p<0.0001$). Fourteen of the 26 nursing home elderly participants detected the difference (53.8%) ($p<0.05$). The proportion of patients who detected the difference tended to be significantly higher in young adults vs. elderly (72.4% vs. 53.8%; $p=0.17$).

Sensory Test 3 compared two viscosities in the honey texture range with the concentration recommended by manufacturer; one sample of NC 3% with a viscosity of 491.3 (1) mPa·s and two samples of RC 2.4% with a viscosity of 292 (3) mPa·s. Of the 29 young adults in panel A, 27 detected which was the different sample

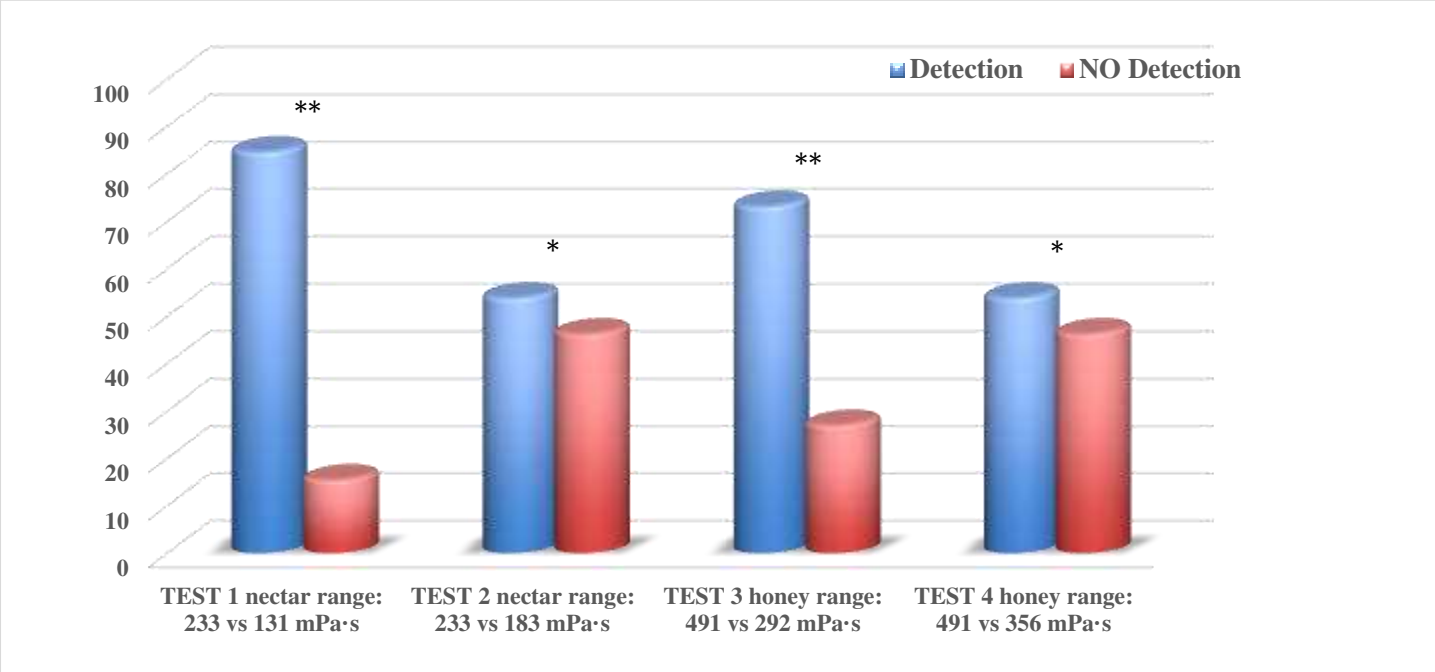
(93.1%) (<0.0001). Of the 26 older adults in Panel B, 19 detected the difference (73.1%) (p<0.0001). The differences in discrimination between young and older adults were at the limit of statistical significance (93.1% vs. 73.1%, p=0.069)

Finally, Sensory Test 4 again compared two viscosities in the honey texture range but with the same concentration both thickeners; one sample of 3% NC with a viscosity of 491.3 (1) mPa·s (honey texture) and two samples of RC with the same concentration (3% with a viscosity of 356.6 (6) mPa·s). Of the 29 members of Panel A (healthy adult), 25 detected the different sample (86.2%) (p<0.0001), while of the 26 elderly, 14 detected the difference (53.8%) (p<0.05). The differences between groups in this case were statistically significant (86.2% vs 53.8%; p=0.016).

The results of the percentage of institutionally elderly people who detected the most viscous sample presented within the nectar and honey texture ranges can be seen in figure 2 and the percentage of correct answers in the healthy adult population can be seen in figure 3.

Figure 2. Comparison of percentage of correct detections of viscosity differences in institutionally elderly people.

297



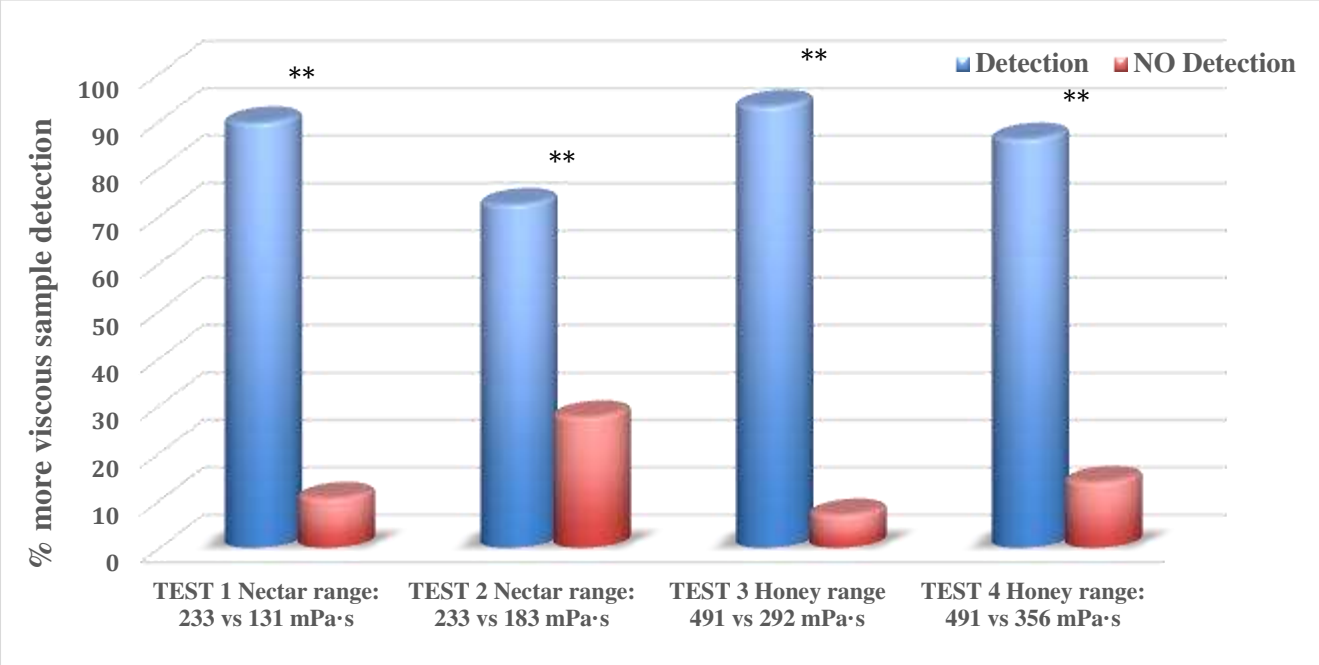
298 Significance level (*p<0.05, **p<0.0001).

299

300 Figure 3. Comparison of percentage of correct detections of viscosity differences in

301 young caregivers.

302



303 Significance level (*p<0.05, **p<0.0001).

4. Discussion

In this study, a sensory test was performed involving adults and institutionalized elderly people to evaluate whether an individual could discern small differences in viscosity in the same range of texture according to the National Dysphagia Diet Task Force[5] among different thickeners based on gums. The rheological properties of thickeners depend on their concentration and shear rate (swallowing strength). The understanding of these characteristics can facilitate an individualized prescription. For the first time, a sensory test carried out on elderly people showed that they can detect sensory differences within the same texture, suggesting that the viscosity ranges of the different textures stipulated by international classifications [10] may be too wide.

The obtained results showed that the rheological behavior of the tested thickeners is non-Newtonian (pseudoplastic), meaning that the viscosity decreases when an external shear force is applied. In relation to the swallowing process, if the food bolus is a pseudoplastic fluid, its viscosity is altered by the propulsion of the tongue or by pharyngeal compression during swallowing, thus decreasing its viscosity [11]. This shear force exerted during swallowing on the alimentary bolus is not the same in a young adult as in an elderly person. Not all products used in clinical practice for the patient with dysphagia present this pseudoplastic behavior [12], however, this pseudoplastic behavior has been described for the majority of thickened fluids [13].

Non-Newtonian rheological behaviors have also been described when analyzing the behavior of a thickener based on xanthan gum, maltodextrins and gum arabic [7] and with thickeners based on gums, starch or a mixture of both [14]. This rheological behavior of thickeners has clinical implications since the elasticity of the bolus contributes to a more pleasant and safer swallowing [15]. Gum-based thickeners have the highest viscosity at slow shear rates, so they may be safer for the elderly and for

329 patients with motor dysphagia who exert less force during swallowing. This behavior
330 its similar to describe by Seo et al [6].
331 NC has a higher viscosity than RC at the same concentration level. When analyzing the
332 thickeners viscosity dissolved in water at 50 s-1, NC reached a higher viscosity than
333 RC with all concentrations except with the 0.5% one. This fact is surprising because
334 the manufacturers for a nectar texture recommend less quantity for RC than for NC,
335 and this is probably due to the fact that the accepted range of viscosity for nectar texture
336 is very wide[10]. The same happens with the honey and pudding texture. Moreover, the
337 higher the amount of grams of commercial thickener used, the greater the difference
338 between NC and RC. These findings have clinical utility because they indicate that
339 thickeners of different composition should not be interchanged the handling is different.
340 This practice can occur in places with a high incidence of dysphagia, such as nursing
341 homes.
342 These results coincide with those of Park et al. [16] who observed that the viscosities
343 obtained in two thickeners, one guar gum-based and the other one xanthan gum-based
344 (both 1% concentration in water), were similar. However, as the concentration
345 increased, the guar gum-based thickener reached a higher viscosity than the xanthan
346 gum-based thickener. This could explain, in a way, why the NC thickener (based on
347 xanthan gum, guar gum and maltodextrins) displayed, in our work, statistically
348 significant higher viscosities with concentrations 1% and over than the xanthan gum
349 and maltodextrin (RC) based thickener.
350 Sopade et al [14] analyzed thickeners based on xanthan gum, whose viscosity results
351 were lower in comparison with those of the present work (NC and RC). They also
352 analyzed a thickener based on guar gum, which reached the highest viscosity values
353 measured at 50 s^{-1} with the lowest concentrations (2452.1 mPa·s with a concentration

of 1.8%). In the same way, the study by Seo et al [6] found that a thickener based on xanthan and guar gums reached higher viscosity than thicker contained only xanthan gum at the same concentration. This suggests a higher thickening power of guar gum compared to xanthan gum.

In our study observed that both thickeners could obtain water viscosities corresponding to nectar and honey textures (around 1000 mPa·s) but the pudding texture was reached with difficulty (>1750 mPa·s). This limitation in its potency could be of relative clinical importance. According to Clavé and García [17], the textures most commonly used in prescriptions by doctors are nectar (60%) and honey (33%), with the pudding texture being the least prescribed (6%). This may be due to the fact that in very thick liquids (pudding textures) patients report poor tolerance and decrease in their liquid intake in addition to increasing their level of satiety [17,18]. In addition, a higher viscosity in the fluid will mean a greater shear effort in the swallowing process [19], and viscosities higher than 1000 mPa·s (and even 800 mPa·s) do not confer many benefits, because they no longer improve safety and efficiency in swallowing according to several recent articles [20,21].

The combination of a rheological analysis with a sensorial type analysis offers for the first time a clear insight into the human capacity of detecting viscosities variations and defines the application of these data on clinical practice, beyond the classic texture classifications. Differences in rheological parameters with similar concentrations were detected by both panel A (young adults) and panel B (elderly) during the sensory study. When the differences in viscosity were high and therefore more distinct, they were perceived by almost all panelists (A and B). However, when they were minimal, it was much more difficult for the elderly in panel B to detect them (detection at the limit of statistical significance), although the great majority of non-elderly adults continued to

perceive them. The result of the elderly participants can be explained by the fact that the difference in viscosity with these concentrations was less than the corresponding one according to the manufacturer and the shear force exerted during the swallowing process is less than that of an adult [22] or their ability to evaluate differences in viscosity is reduced.

Steele and Van Lieshout [23] suggested that motor and neurological ability decreases with advancing age, so changes in the ability to differentiate viscosities may appear, indicating that larger cohort studies are needed. Clinically this clearly means that the force exerted by the mouth is different in healthy adults (panel A) and in the elderly (panel B). The sensory analysis showed that the classic classification of textures (nectar, honey and pudding) probably needs a review. We should take into account the real capacity of an individual to detect viscosities. It is verified with our study that the differences in viscosity, even when they are small, are detectable by people. Therefore, the classification of nectar, honey and pudding probably should be refined through rheological analysis. The viscosity ranges could be narrower to better suit the needs of each patient. Currently, the latest initiative of the IDDSI [24] consists of the creation of four new ranges of liquids textures but uses qualitative methods with a syringe.

To our knowledge our study is the first one, in which a sensory test is performed in elderly people and the first in which rheology is used to investigate the viscosity of different commercial thickeners with a wide range of concentrations. Most of the works published are limited to one or two thickeners and to very specific concentrations.

However, there are some limitations in our study. The variations in the sensory tests may not be entirely associated with rheological differences since it cannot be ruled out that the taste, smell or other sensory characteristics may change slightly with different concentrations. Moreover, in sensory tests, the population studied was a population

404 without diagnosed swallowing disorders; therefore, the results cannot be directly
405 extrapolated to patients with different types of dysphagia, although there is no reason
406 to think that the results could be different. On the other hand, it was not possible to
407 determine whether the different rheological characteristics was associated with greater
408 safety during swallowing. Studies by means of videofluoroscopy would be necessary
409 to evaluate the risk of aspiration with the different viscosities.

410 **5. Conclusions**

411 For the first time we have observed that both institutionalized elderly and their younger
412 caregivers are able to discern small differences in viscosity in nectar and honey textures.
413 These results are important on a clinical level because it could signify that the
414 classification of nectar, honey and pudding should be revised through rheological
415 analyses. The sample of healthy adults detected small differences in viscosity more
416 effectively, so the force exerted by the mouth during swallowing may be different
417 between healthy adults and the elderly. Furthermore, at the same concentration, each
418 thickener produces a different viscosity, detectable even by institutionalized elderly
419 people. Thickeners are not interchangeable with each other even if they belong to the
420 same group (gum-based thickeners). Each one has a different composition, which
421 influences its power to increase the viscosity of the water and present a different
422 handling.

423 Further studies are needed to verify whether the rheological characteristics of
424 thickeners influence the safety, adherence, or patient preference for different thickeners
425 according to the type or intensity of their dysphagia.

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429 **Abbreviations**

430 NC: Nutilis Clear ®; RC: Resource Clear ®; mPa·s: milliPascals per second; CEICA:
431 Research Ethics Committee of the Autonomous Community of Aragon; SD: Standard
432 Deviation; IDDSI: International Dysphagia Diet Standardization Initiative

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438 and A.S-P.; formal analysis, J.M.A-M., A.C.S-G., and A.S-A.; investigation, F.C-Ch.
439 and A.S-P., J.P-N., and A.C-M.; writing—original draft preparation, F.C-Ch., and A.S-
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441 A.S-P. All authors have read and agreed to the published version of the manuscript.

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444 **Availability of data and materials**

445 The datasets analyzed in the current study will be available from the corresponding
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447 of the Ethics Committee of Aragón for Clinical Research (CEIC-A)

448 **Ethics approval and consent to participate**

449 The study was approved by the local ethics committee (Research Ethics Committee of
450 the Autonomous Community of Aragon: CEICA) (registration number C.P.-C.I.
451 PI15/0331). All participants signed an informed consent form before participating in
452 the study.We confirm that all methods were carried out in accordance with relevant
453 guidelines and regulations.

454 **Consent for publication**

455 Not applicable.

456 **Competing interests**

457 A.S-P. has received speaker's fees and has worked on research projects of Abbott
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459 A.C.S-G., and A.S-A., declare no conflict of interest related to this article.

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Figures

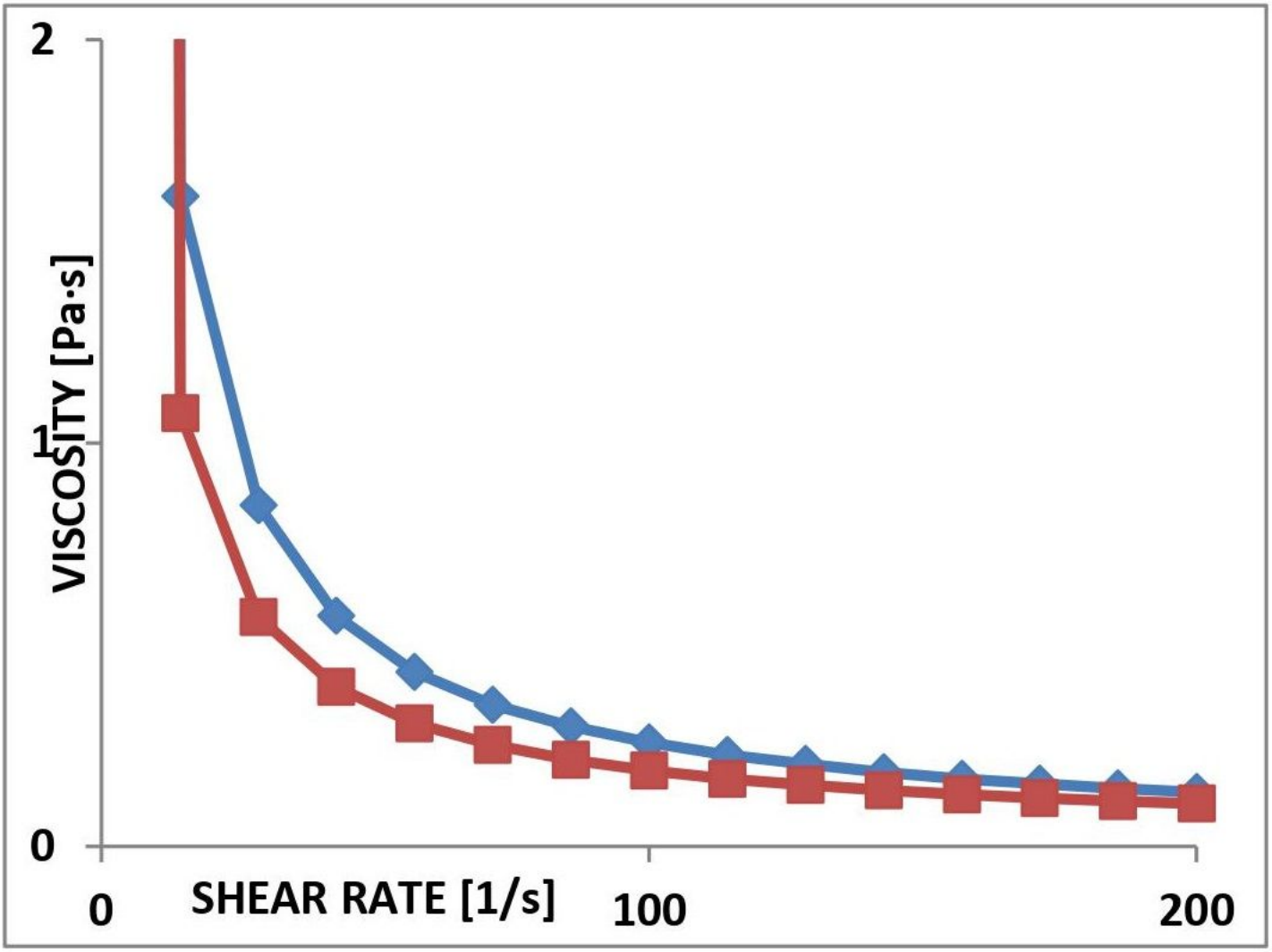

Figure 1

Graphical representation of the viscosity curve with the shear rate at a concentration of 3%. * The purple line corresponds to the red to RC and the blue to NC.

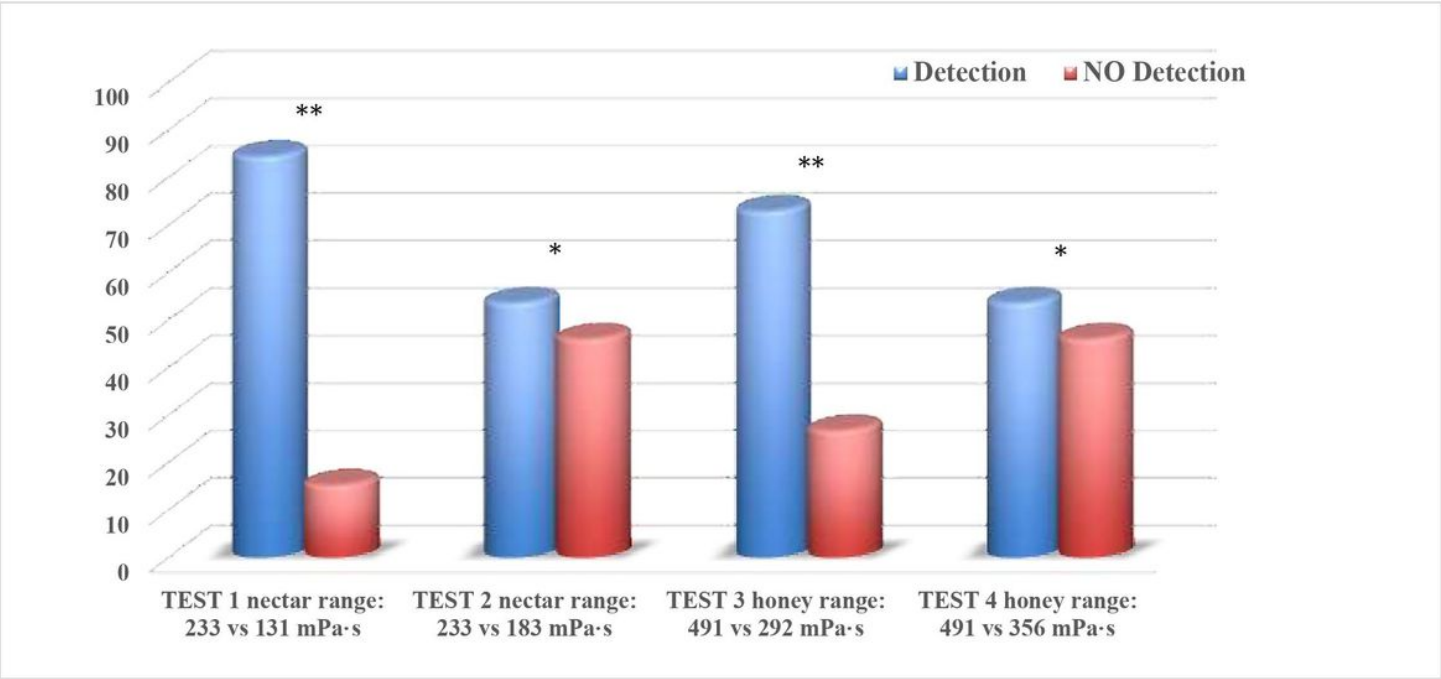

Figure 2

Comparison of percentage of correct detections of viscosity differences in institutionally elderly people. Significance level (*p<0.05, **p<0.0001).

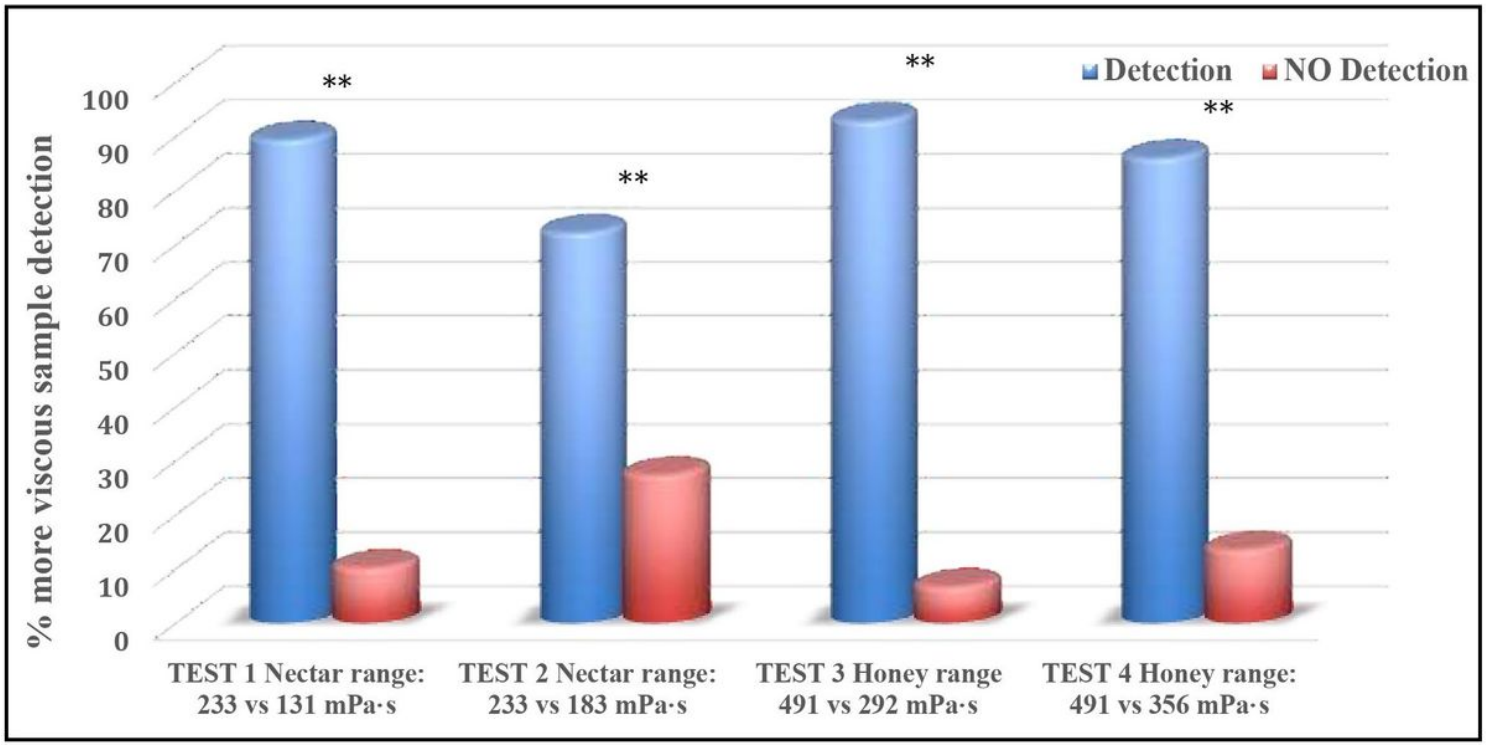

Figure 3

Comparison of percentage of correct detections of viscosity differences in young caregivers. Significance level (*p<0.05, **p<0.0001).