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Development of medium fat plant-based mayonnaise using chickpea (*Cicer arietinum*) and green gram (*Vigna radiata*) and sensory evaluation using fuzzy logic

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Abstract
Mayonnaise and salad dressing have gained massive popularity among the young population worldwide. The legumes are good sources of protein and can be used as an egg replacer in mayonnaise. This study focuses on developing healthy mayonnaise options from green gram and chickpea to make it an entirely plant-based product. The chickpea and green gram were soaked for 12 hrs and cooked at 100 °C for 20 min, and after grinding, the extract was used to prepare mayonnaise in addition with chilli-mint paste. The physicochemical analysis has shown no significant difference among moisture, fat, carbohydrates, and ash. The significant difference was seen in protein content of green gram mayonnaise (4.14 ± 0.1%) and chickpea mayonnaise (3.62±0.27%). Similarly, crude fiber content was 6.33±0.12% in the chickpea mayonnaise and 3.9±0.1% green gram mayonnaise. Chickpea mayonnaise has shown high shear-thinning properties than green gram mayonnaise. The sensory evaluation revealed that mayonnaise made with chickpea was more accepted in terms of colour, appearance, and texture. At the same time, green gram flavoured mayonnaise was preferred for taste and, mouthfeel. The best sample was chosen by using fuzzy logic in which all samples were compared with commercial sample and consumer expectations for ideal mayonnaise and developed sample were found acceptable.

Keywords: Mayonnaise, chickpea, green gram, vegan, rheological properties, fuzzy logic

1. Introduction

Mayonnaise is a semisolid food emulsion product containing vegetable oil, whole egg or egg yolk, milk or skimmed milk powder, vinegar, sugar, salt, and spices. According to the US FDA, mayonnaise should not contain less than 65% of oil by weight (FDA *et al*., 2018) [5]. The global mayonnaise and salad dressing market forecast during 2021-2026 is projected to grow at a CAGR of 4%. The acceptance of international cuisine by the young population and middle-class families is responsible for CAGR (Dublin, 2021) [4].

The mayonnaise is oil in water emulsion stabilized by an emulsifier, usually a protein or gelling agent. Eggless option for salad dressing is now dominating the market over the traditional egg-based mayonnaise (Fernandes & Mellado, 2018) [6]. Recently, major populations are converting to a vegan diet, i.e., they prefer food obtained from the plant source. The trend for vegan food has recently risen due to the availability of healthier alternatives for animal sources, replicating physical and sensory properties (Tso *et al*., 2021) [15]. Earlier, people prefer vegan food because they are against animal cruelty, and some follow the regional ethics of not hurting animals.

Now, veganism has taken itself to the next level by avoiding the ingredients/ raw materials from animal sources like milk, egg, etc. So, the replacement of milk and egg, the primary stabilizing and emulsifying aid in emulsified sauces, is explored. Using soy protein and stabilizers such as plant exudates, and modified starches were alternatives for milk and egg. Though soy is well studied, only limited scientific information is available on the stabilizers. There is a high demand for other options from other plant sources, e.g., Pulse/legume extracts like chickpea, green gram, and black gram. Among the plants, the underutilized or least explored pulses are gaining importance other than soy due to their protein content compared to cereal grains and the presence of a significant amount of macronutrients.

Pulses are also called poor man meat because of their rich nutritional profile. Pulses provide protein and fiber and are a good source of vitamins and minerals such as iron, zinc, folic acid, and magnesium.

Additionally, the tannin, saponins, and phytochemicals present in the pulses possess antioxidant and anti-carcinogenic effects (Kishor *et al*., 2017) [7]. Proteins, carbohydrates, and other constituents are primarily responsible for legume flour functional characteristics: oil and water absorption capacity, foaming, emulsifying, texture, gel formation, and viscosity, which improve food product efficiency and performance (Shevkani *et al*., 2019) [13].
The application of fuzzy methods allowed for a different ranking of all samples based on particular quality features and quality attributes, providing clarity on product acceptability and comparative usefulness of sensory qualities such as taste, mouthfeel, aftertaste, color, and aroma. (R. Kumar *et al*., 2021) [8]. As a result, enhancing and modifying product formulations became more accessible, and key marketability variables could be readily monitored.

Materials and Methods

The major ingredients as chickpea (*Cicer arietinum*), green gram (*Vigna radiata*), sugar, salt, vinegar, and sunflower oil, were purchased from the local market Thanjavur, Tamilnadu, India. The mustard sauce (Veeba American Mustard Sauce, 320g) and standard vegan mayonnaise (Veeba Eggless Mayonnaise, 250g) for sensory comparison were purchased from an online store (Amazon). Green gram and chickpeas were cleaned by hand to eliminate dirt and other contaminants before being stored till used.

Preparation of green gram and Chickpea extract:

The green gram and chickpea were soaked separately in 1:4 (w:v) water for 12 hrs, discarding soaked water. Open pan cooking at 100 °C for 20 min with double amount water. Weight has taken after cooling, and water was added in a 1:1.5 (w:v) ratio and ground in a colloidal mill for 10 min. The extract was obtained and stored at 4 °C until further use.

Preparation of Mayonnaise

The Low-fat mayonnaise was formulated using Tavakoli *et al*. (2021) [14] with slight modification, replacing water and gum with chickpea and green gram extract detailed in Table no 1. All ingredients measured and mixed expect oil added slowly during mixing with a hand blender (Philips Daily Collection HL1655/00 250-Watt Hand Blender) for 10 min. The half unflavoured mixture named plain mayonnaise was stored in the bottle at 4 °C, and 1% chilli-mint paste was added to the half plain mayonnaise mixed and stored at 4 °C until further use.

Proximate chemical composition:

The moisture, fat, ash, protein, and carbohydrate content of mayonnaise was done according to (AOAC, 2005) methods. The moisture was determined in 2 steps. In the first step, the sample is heated in an oven at 50 °C until constant mass. Then, 2 g of each sample was heated in an oven at 105 °C until constant mass. Ash content of the sample was determined by igniting, five grams of the sample placed in the crucible in a muffle furnace at 550°C for 3 hours or more until light grey ash was obtained and taking initial and final weight. The samples' protein content was determined using the Kjeldahl method, and to the estimated total nitrogen, 6.25 was multiplied to get a total nitrogen basis. The fat content is calculated by using the petroleum ether extraction method. The amount of moisture, fat, protein, and ash content was subtracted from 100 to obtain the total carbohydrates (Bhosale *et al*., 2021) [1].

Color and pH

The Hunter Lab colorimeter (Hunter lab color flex EZ setup 82) was used for measuring the color of wine samples. A white tile and black tile were used as reference tiles for calibrating the equipment. The color value was explained in terms of L*, a*, and b* values. L* denotes the lightness ranging from black to white in which L*; 0 is dark, 100 is light, while a* represents greenness +60 to redness − 60, and b* characterizes blueness +60 to yellowness – 60 (Y. Kumar *et al*., 2021) [9] and the sample was added to the crucible and covered with black lid and reading were taken in triplicates. The value of ΔE was calculated to know the total colour difference between control (standard) and sample by using the following formula;

$$\Delta E^* = \sqrt{(L - L*)^2 + (a - a*)^2 + (b - b*)^2}$$

The pH was determined by direct measuring in a digital pH meter; the electrode was directly placed in the sample and cleaned before each reading. The values were taken in replicates, and the pH meter was calibrated using a pH buffer of 4.0, 7.0, and 9.2 before every experiment.

Rheology of mayonnaise

Rheological measurements were performed with a rheometer (Anton Paar MCR 52, Austria) using both controlled shear rate and shear stress via a plate of 50 mm diameter. The mayonnaise sample was loaded using a spatula, and the upper plate was lowered to achieve a designated gap distance of 1.00 mm performed by Y. Kumar *et al*. (2021) [9]. The experiments were conducted at 20 °C, with fresh samples loaded every time. Herschel–Buckley fluid model gives an excellent result for materials with true yield value, i.e., which remain solid till particular shear stress and start flowing above that shear stress. Equation $\tau = \tau_o + K\dot{\gamma}^n$ where ′ τ′ (Pa) is the measured stress, ′ τ_o ′ (Pa) is the measured yield stress, 'K' (Pa.sn) is the consistency index, 'n' (dimensionless) is the flow behaviour index, and '$\dot{\gamma}$' (s^{-1}) is the shear rate measured.

Sensory analysis

Five points hedonic scale was adopted for sensory evaluation of mayonnaise samples for Appearance, Taste, Mouthfeel, Texture, and Overall Acceptability (Point indicates 5-Excellent; 4-Good; 3-Medium; 2-Fair; and 1-Not satisfactory). A panel of 40 panellists was chosen for sensory analysis, out of which 20 were male, and 20 were female. Fuzzy analysis was done in excel using the method explained by Dhar *et al*. (2021) [3]; R. Kumar *et al*. (2021) [8] to choose the best sample-based on sensory results.

Statistical analysis

All studies were carried out in triplicate, and all findings were expressed as mean ± standard deviation. For statistical analysis, Minitab® 17.3.1 program was used. One-way variance analysis (ANOVA, with Tukey comparison) with a confidence level of 95% and significance level α= 0.05 was performed.

Results and Discussion

Proximate chemical composition

The proximate chemical composition of developed mayonnaise is prescribed in Table No 2. The protein content shows a significant difference between chickpea and green gram mayonnaise. The highest amount of protein was seen in green gram mayonnaise about 4.14 ± 0.1% in green gram flavoured (GGF) and 3.97±0.1% in green gram plain (GGP) mayonnaise, 3.62±0.27% in chickpea flavoured (CPF), and 3.5±0.35% in chickpea plain (CPF) mayonnaise. There was no major difference between moisture, fat, carbohydrates, ash, and energy values between all mayonnaise samples, except the crude fiber content, which was high in the chickpea mayonnaise 6.33±0.12% in CPP and 6.23±0.06% in CPF, while in green gram mayonnaise it was 3.9±0.1% in GGP and 3.93±0.15% in GGF. The energy values ranged from 213.72 to 221.25 kcal / 100 g. The value of protein was much higher as compared to the commercial mayonnaise, which was 0.10%. No significant difference was seen in energy values, so both mayonnaise samples. So, nutritionally both samples can be accepted.

Color and pH
The Color measurements of mayonnaise samples are shown in Table 3. The L* (lightness) of mayonnaise has a major impact on the appearance of the product. The highest L* (81.43) among all mayonnaise formulations after the control sample (L*- 88.79) was found in mayonnaise formulated with CPP then by CPF (L*- 78.77), and least lightness was seen in GGF may be due to more amount of green gram husk and chill-mint paste (L*- 66.14). The lowest value of ΔE explains the more lightness of the product, which shows close properties to standard or control sample. The sample CPP has the lowest ΔE value due to the yellowish colour of the product and raw materials, which lead to the improved colour of the mayonnaise. The blackish green colour was seen for green gram mayonnaise and was getting darker with time and cream white for chickpea mayonnaise. So, chickpea mayonnaise has shown the preferable values for colour to a green gram. There was no significant difference between pH values of mayonnaise prepared. This was due to a similar amount of acetic acid was added to all formulations.

Rheology
Viscosity: Mayonnaise viscosity is an important quality indicator. The texture of commercial mayonnaise is thick and creamy. Furthermore, mayonnaise with a low viscosity is sensitive to phase separation. The highest thickness was seen in the commercial control mayonnaise sample which apparent viscosity ranged from 158 to 4.43 Pa.s. Sample GGF and GGF showed the highest apparent viscosity, ranging from 130 to 2.22 Pa.s and 97.16 to 2.26 Pa.s, as seen in Figure 2. The lowest viscosity was seen in CPP and CPF ranging from 30.67 to 0.48 Pa.s and 23.56 to 0.45 Pa.s, but grittiness was more seen in GGF and GGP samples than CCP and CCF mayonnaise; this was due to the outer husk of green gram. During the storage of green gram mayonnaise, the release of oil at the surface was seen; this may be due to grittiness. At the same time, no oil was seen at the top of chickpea mayonnaise; this may be due to the emulsifying properties shown by chickpea after cooking (Meurer *et al.*, 2020; Mustafa *et al.*, 2018; Raikos *et al.*, 2019) [10, 11, 12].

Flow behaviour and consistency index: Form the results obtain, mayonnaise shows shear-thinning, i.e., pseudoplastic behaviour, although it may show both behaviours simultaneously. Pseudoplastics fluids have a viscosity that drops significantly when a shearing force is applied but returns to normal once the shearing force is withdrawn. According to Chung *et al.* (2016) [2], shear-thinning behaviour in emulsions is caused by an irreversible structural breakdown caused by the applied shear rate, resulting in the spatial redistribution of the emulsified oil droplets. The graph explaining shear stress [Pa] vs shear rate [1/s] explains more about flow behaviour properties. All samples show shear-thinning behaviour except CPP shown shear thickening properties. In the rest samples, the CPP shown the highest shear-thinning properties, followed by GGP and GGF. After control, the highest consistency was seen in green gram mayonnaise than chickpea mayonnaise, but chickpea mayonnaise is suitable for use as a salad dressing in food. For improving the consistency of chickpea mayonnaise amount of water added for grinding can be reduced. So, both products can be similarly accepted.

Sensory
Mayonnaise made from green gram (GG) and chickpea (CP) was further divided into plain (CPP and GGP) and flavoured (CPF and GGF) after addition of chilli-mint paste to suppress beany flavour, and were compared with commercial vegan mayonnaise available in the market for comparing sensory parameters Colour, Appearance, Taste, Mouthfeel, Texture, Overall Acceptance (OA). The five-point sensory score was collected from 40 semi-trained panellists. Mean values were calculated (Table 5), and radar (spider web) graphs were plotted to get the panellist's preferred sample. The most preferred sample for colour and appearance was CPP, and for taste and mouthfeel, GGF was most preferred, but choosing one best sample from all samples was difficult, as seen in Figure 4. All samples showed similar preferences, according to the panellist.
According to the suggestion from the panellist's grittiness in green gram samples needed to be reduced, and colour needed to be improved, and chickpea was primarily preferred for colour, appearance, mouthfeel due to low grittiness and suggested to use it as a salad dressing. During comparison between only plain mayonnaise, the chickpea mayonnaise has a low beany flavour compared to the green gram so CPP was more preferred then GGP. So, after adding a suitable flavour and maintaining proper consistency, chickpea mayonnaise can be the best alternative.
So, the application of fuzzy logic for interpretation was performed in excel using the method for performing statistical steps explained by Dhar *et al.* (2021) [3] and was compared with data are taken from panellists for the ideal sample should contain. The results obtained in scale factor Not satisfactory-F1, Fair-F2, Satisfactory-F3, Good-F4, Verygood-F5, Excellent-F6 and sample which includes the highest value is considered a preferable sample. After applying fuzzy interpretation in Table 6, all samples were shown in the Good-F4 scale, but the GGF was the most acceptable sample for all sensory parameters.

Conclusion
The present study focuses on developing plant-based vegan mayonnaise from green gram and chickpea to replace traditional mayonnaise made from egg and full fill protein amount, which is very low in commercially available vegan mayonnaise. This study primarily focuses on Physicochemical, rheological, and sensory properties. Thus, both mayonnaises are don't have much significant difference in nutritional properties except protein which was higher in

green gram mayonnaise and crude fiber which were higher in chickpea mayonnaise. It is concluded that the mayonnaise made from green gram has more protein content, good rheological properties by having higher viscosity and high shear thinning rate, and most acceptable sensory sample according to fuzzy logic interpretation. Further, the study concludes that the mayonnaise made from chickpea is also accepted in colour and appearance parameters. Due to its rheological property, it can be used as a salad dressing in food products. Thus, the future scope of the study should be focused on reducing grittiness from green gram mayonnaise, improving the consistency of chickpea mayonnaise. So, both samples can be accepted equally; while comparing plain mayonnaise to commercial mayonnaise, chickpea was primarily preferred and can be used for further studies.

Author contribution statement

Kadam Mayur Raghunath: Research work, Writing - original draft and Editing. Shanmugam Akalya: Conceptualization, Reviewing, Editing and Supervision. Bhosale Yuvraj Khasherao: Fuzzy modelling and Reviewing and Editing.

Declaration of interest

The authors declare no conflict of interest.

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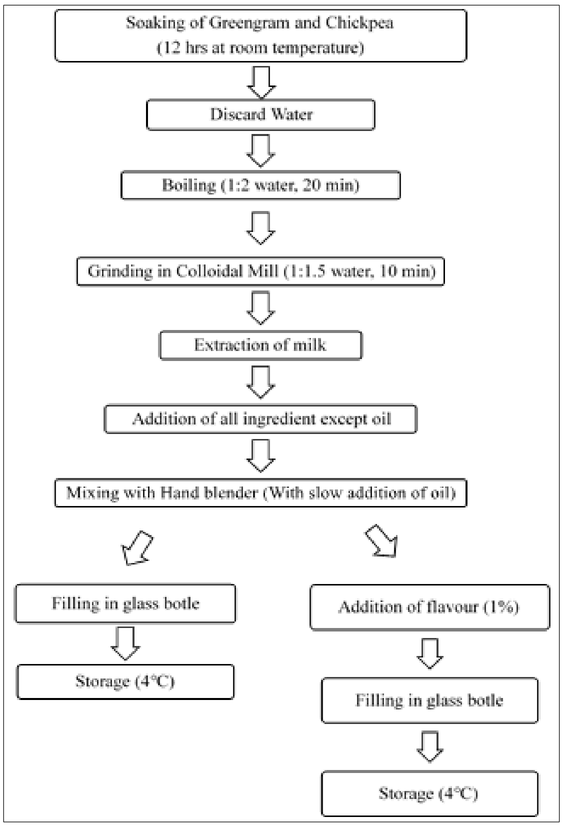


Fig 1: Process flow for preparation of mayonnaise from green gram and chickpea

Table 1: Ingredient formulation for mayonnaise preparation

Ingredients	CPP	CPF	GGP	GGF
Chickpea	60%	60%	-	-
Green gram	-	-	60%	60%
Oil	30%	30%	30%	30%
Vinegar	4%	4%	4%	4%
Sugar	3.5%	3%	3.5%	3%
Salt	1.5%	1%	1.5%	1%
Mustard sauce	1%	1%	1%	1%
Flavour (Chilli-mint paste)	-	1%	-	1%

CPP-Chickpea plain mayonnaise, CPF- Chickpea flavoured mayonnaise, GGP- Green gram plain mayonnaise, and GGF- Green gram flavoured mayonnaise

Table 2: Proximate chemical composition

Sample	Moisture (g/100g)	Protein (g/100g)	Fat (g/100g)	Carbohydrate (g/100g)	Fiber (g/100g)	Ash (g/100g)	Energy value (kcal/100g)
CPP	56.36 ± 1.05^{a}	3.5 ± 0.35^{b}	14.07 ± 1.36^{a}	18.22 ± 0.31^{a}	6.33 ± 0.12^{a}	1.53 ± 0.22^{a}	213.47 ± 10.04^{a}
GGP	56.76 ± 0.11^{a}	3.97 ± 0.1^{ab}	14.53 ± 1.21^{a}	18.99 ± 1.57^{a}	3.9 ± 0.1^{b}	1.85 ± 0.29^{a}	222.62 ± 4.8^{a}
CPF	56.16 ± 0.76^{a}	3.62 ± 0.27^{ab}	13.93 ± 1.4^{a}	18.46 ± 0.45^{a}	6.23 ± 0.06^{a}	1.59 ± 0.19^{a}	213.72 ± 10.2^{a}
GGF	56.72 ± 0.36^{a}	4.14 ± 0.1^{a}	14.2 ± 0.4^{a}	19.22 ± 0.5^{a}	3.93 ± 0.15^{b}	1.78 ± 0.2^{a}	221.25 ± 2^{a}
($P\leq 0.05$)							

Table 3: pH and colour values for mayonnaise samples

Sample	pH	L*	a*	b*	ΔE
CPP	4.4±0.03	81.43±0.03	1.08±0.07	28.25±0.07	22.44±0.07
GGP	4.48±0.06	68.38±0.08	-1±0.01	24.03±0.02	26.47±0.05
CPF	4.43±0.04	78.77±0.14	0.15±0.02	27.02±0.01	22.27±0.07
GGF	4.47±0.02	66.14±0.16	-0.98±0.01	24.95±0.02	28.79±0.14
Control	-	88.79±0.01	-1.35±0.01	7.19±0.01	-
($P\leq 0.05$)					

Table 4: Herschel Bulkley rheology model parameters of mayonnaise

	τ_o (Pa)	K	n	R2	SD
CPP	30.67075	0.012388	1.96155	0.635385	3.09325
CPF	19.095	2.59292	0.588645	0.70526	2.55445
GGF	116.9513	16.03473	0.495827	0.980787	2.5127
GGP	68.07	37.71625	0.394795	0.985305	2.86245
Control	104.476	53.2555	0.401865	0.99737	3.1035

τ_o - Yield stress (Pa), K- Consistency coefficient (Pa.s^n), n- Flow behaviour index (dimensionless), R^2 - Determination coefficient, SD- Standard deviation

Table 5: Mean Sensory score for mayonnaise

	Colour	Appearance	Taste	Mouth feel	Texture	OA
Control	4.48±1.01^a	4.35±0.92^a	4±1.18^a	4±1.06^a	4.5±0.85^a	4.2±0.94^a
GGP	4.23±0.62^{ab}	3.85±0.66^b	3.8±0.82^a	3.9±0.74^a	3.6±0.9^b	3.68±0.73^b
GGF	3.4±0.71^c	3.35±0.83^c	3.7±0.79^a	3.53±0.75^a	3.33±0.83^b	3.4±0.71^b
CPP	3.98±0.73^b	3.85±0.7^b	4.03±0.86^a	3.63±0.87^a	3.55±0.78^b	3.73±0.78^{ab}
CPF	3.33±0.76^c	3.15±0.86^c	3.95±0.64^a	3.88±0.65^a	3.28±0.78^b	3.58±0.75^b

Table 6: Fuzzy scaling result for the mayonnaise sensory

Scale factor	Control	GGP	GGF	CPP	CPF
Not satisfactory, F1	0.0000	0.0044	0.0029	0.0000	0
Fair, F2	0.0417	0.0623	0.0550	0.0317	0.03429
Satisfactory, F3	0.3316	0.1781	0.1697	0.1258	0.1327
Good, F4	0.7571	0.2167	0.2222	0.2125	0.21701
Very good, F5	0.8219	0.0982	0.1125	0.1544	0.14888
Excellent, F6	0.2558	0.0094	0.0119	0.0353	0.03028

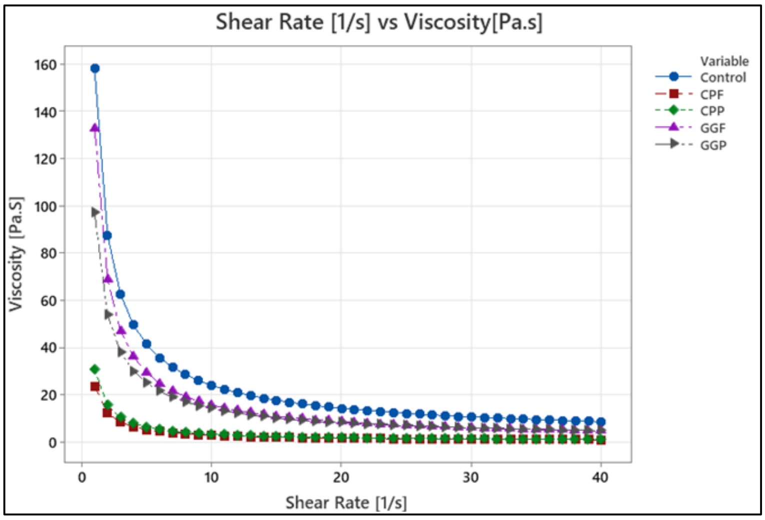
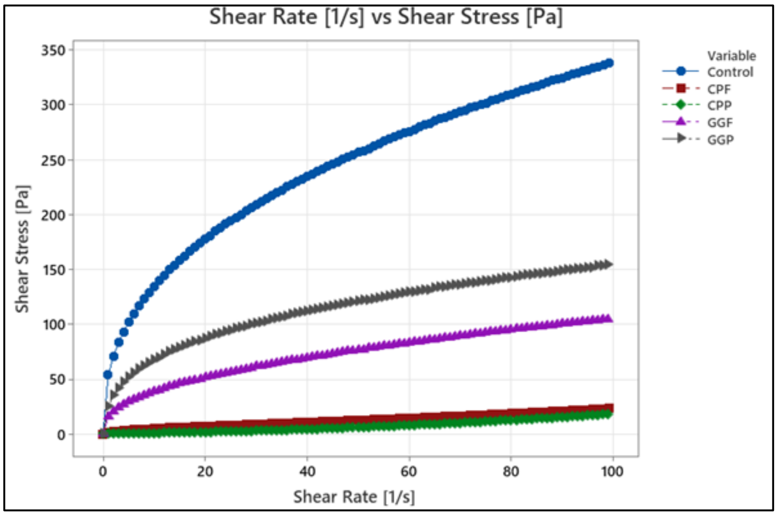


Fig 2: Rheological properties of developed mayonnaise (Shear rate [1/s] vs viscosity [Pa.s])



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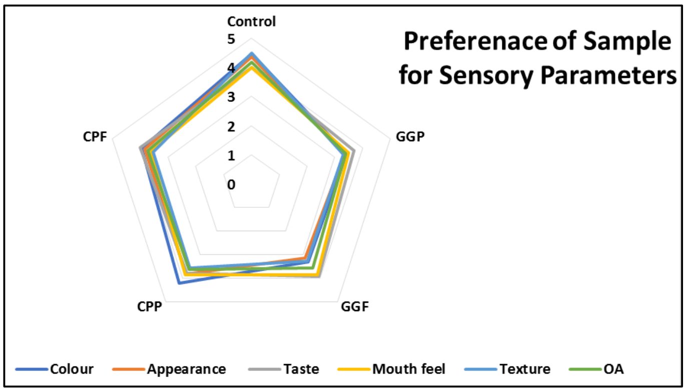

Fig 4: Sensory Radar/Spider chart for developed mayonnaise

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