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Physical, rheological and textural characterization of herbal seasoning enriched with oyster mushroom (*pleurotus sajor-caju*) powder

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Abstract

The influence of oyster mushroom (pleurotus sajor-caju, PSC) powder on the physical properties of herbal seasoning (HS) was investigated. The pH, total solid, viscosity, rheology and texture of semi solid HS containing different PSC powder level (0%, 20%, 40%, 60%, 8%, 100% w/w) of coconut milk powder were measured. The pH of the products were in the range of 4.05 - 4.15. Rheological behavior was characterized by oscillatory rheometry. Stress sweep, frequency sweep and steady stress experiments were conducted to study the behavior of the products. The products showed non Newtonian characteristic or shear thinning. All samples were G'> G'' showed the gel like network. In addition, the back extrusion rig texture analysis showed the correlation among the samples were also studied. Total substitution of PSC powder (100% w/w) in the formulation resulted more viscous product and the combination of the coconut milk powder and PSC powder showed the best spreadability and flow to the product characteristics. No added PSC powder (0% w/w) showed the least viscous products and the less moduli among the samples studied. The present study suggested the incorporation of more than 40% PSC powder to replace coconut milk powder give better flowability and not affect the viscosity of the products.

Introduction

Fresh mushrooms have been used since ancient time ago. These fungi were highly perishable if not stored appropriately (Bano and Rajarathnam,1988; Burton and Noble,1993). They are widely known all over the world for their nutritional properties (Kalac, 2009). In addition, this edible mushrooms are accepted worldwide due to their flavour, nutritional value and their distinctive texture. Recently, they have been recognized as a "forgotten source of nutrients" and also as "white vegetables" (Weaver and Marr, 2013). On the other hand, mushroom farming is practiced in more than 100 countries and the annual production of mushroom is expected to reach 7 million metric tons in the next 10 years (Kumar *et al*., 2011).

Various techniques have been done to prolong the shelf life of oyster mushroom. Processing of oyster mushroom into powder form have been practiced and applied all over the world. In spite, the addition of PSC powder in selected food formulations will enhance the nutritional value of such products. Compared to vegetables, edible mushrooms are high in protein and have a good balance of vitamins, minerals, calcium, phosphorus, iron, magnesium, soluble and insoluble fiber, beta-glucans, chitin, phenolic compounds and ribonuclease (Fukushima *et al*., 2000; Silva *et al*., 2002; Mattila *et al*., 2002; Ngai and Ng, 2004; Manzi *et al*., 2004). In general, the content of protein in mushrooms was higher compared to most other vegetables (Bano and Rajarathnam, 1988) and most of the wild plants. They are considered sources of organic nutrients such as digestible proteins, carbohydrates, fibre and certain vitamins, as well as minerals and antioxidants (Nnorom *et al*., 2012)

Nowadays, convenience foods offer the concept such as Ready to Cook (RTC) and Ready to Eat (RTE) food which food can be consumed immediately after thermal treatment. Therefore, customers only need minimal preparation of the food (Sloan, 2005). The introduction of mushroom as an ingredient in herbal seasoning (HS) which is one type of ready to eat food will give the new dimension of packaging and the study of their nutritional values. PSC powder also has already been incorporated in chicken patties (Wan Rosli *et al*., 2011), beef products (Wan Rosli and Solihah, 2012), bakeries (Wan Rosli *et al*., 2012), rice based products (Aishah and Wan Rosli, 2013),

HS is prepared by cooking with other ingredients in the formulations (Table 1). The viscosity is to be obtained to ensure the conformity with other batches of food products. Hence, the quality procedures

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Table 1. Raw ingredients used in HS enriched with PSC powder preparation

Ingredients (%)	PSC Powder Level (%)					
	A (0%)	B (20%)	C (40%)	D (60%)	E (80%)	F (100%)
PSC powder	0	4	8	12	16	20
Coconut milk powder	20	16	12	8	4	0
Dried chili	1.6	1.6	1.6	1.6	1.6	1.6
Fresh turmeric	1.1	1.1	1.1	1.1	1.1	1.1
Ginger	1.7	1.7	1.7	1.7	1.7	1.7
Galangal	0.8	0.8	0.8	0.8	0.8	0.8
Onion	20.4	20.4	20.4	20.4	20.4	20.4
Shallot	9.4	9.4	9.4	9.4	9.4	9.4
Garlic	2.4	2.4	2.4	2.4	2.4	2.4
Cumin powder	0.8	0.8	0.8	0.8	0.8	0.8
Fennel powder	0.8	0.8	0.8	0.8	0.8	0.8
Coriander	1.6	1.6	1.6	1.6	1.6	1.6
"Kerisik"	6.3	6.3	6.3	6.3	6.3	6.3
Dried lime	0.4	0.4	0.4	0.4	0.4	0.4
Salt	2.4	2.4	2.4	2.4	2.4	2.4
Black pepper	0.4	0.4	0.4	0.4	0.4	0.4
Lemon grass	1.6	1.6	1.6	1.6	1.6	1.6
Water	26.7	26.7	26.7	26.7	26.7	26.7
Citric acid	0.4	0.4	0.4	0.4	0.4	0.4
Sugar	1.6	1.6	1.6	1.6	1.6	1.6
'Bunga Kantan' (*Etlingera elatior*)	10	10	10	10	10	10
Turmeric leaves (*Curcuma Longa* L)	20	20	20	20	20	20
'Daun limau purut' (*Citrus Hystrix*)	10	10	10	10	10	10
'Pegaga' (*Centella asiatica* L)	60	60	60	60	60	60

(A=0% PSC, B=20% PSC, C= 40%PSC, D= 60% PSC, E=80% PSC, F=100%PSC)

such as pH, water activity, total soluble solid has to be recorded to ensure the quality and stability of products is maintained all the time. Then, knowledge of the rheological behavior of paste is essential for product development and evaluation of the process equipment (Ahmed, 2000). The appearance and the flow of the products is important as consumers are interested to certain product by looking at these attributes such as viscosity. These factors will give the first impression of acceptance by the consumers. Textural quality attributes of food may be evaluated by descriptive sensory (subjective) or instrumental (objective) analyses. Over the years, a wide range of instrumental tests has been used in both research and industry to assess food texture. Thus, the food industry requires instrumental methods to measure the textural characteristics of food products (Bourne, 2002). In terms of fluid flow, materials may be classified as either Newtonian or non-Newtonian fluids. Typically, it is known that viscoelastic properties play dominant roles in the handling and quality of product (Rao and Steffe, 1992).

Numerous studies have been conducted on mushroom and products on nutritional value and antioxidants properties, but seldom focusing on the physical properties mainly the rheological and textural characteristics of finished products. Hence, the study was undertaken to identify the most appropriate PSC powder to be introduced in the formulation herein is HS. Therefore, the objectives of this work were to investigate the textural and rheological characteristics and their resulted to the viscosity of the HS.

Materials and Methods

Preparation of PSC powder

The dried oyster mushroom samples (Pleurotus sajor-caju, PSC) were supplied by Anjaad Sdn. Bhd., Malacca, Malaysia which underwent a drying technique under Biodehydration™ system. The dried samples were ground into fine powder by using food blender brand National MX 895M with 1mm mesh size and kept in plastic packaging prior to analysis.

Preparation of herbal seasoning with different percentage of PSC powder

Herbal seasonings (HS) were prepared by using local herbs, blended spices, oyster mushroom powder and coconut milk powder as shown in Table 1. All local culinary herbs were purchased from local market. Coconut milk powder was substituted with PSC powder at the level of 0% (A), 20% (B), 40% (C), 60% (D), 80 % (E) and 100% (F). Composite powders and other dry ingredients were mixed with culinary herbs in a jacketed kettle before water was added. The pH of the mixture was adjusted to less than 4.5 with citric acid and the mixture was then heated to boiling. This is followed by hot filling into bottles of 230 gram followed by processing in boiling water until the centre of the product reaches 93^{o}C. The finished products were kept at room temperature until further analyses.

pH, total solid content and viscosity

The pH of the HS was determined using a bench top pH meter (Metrohm Model,744, Herisau, Switzerland). The readings were taken in triplicate. Total solid content (TSC) of each HS was measured by drying five grams of HS in an oven (Memmert UE 600, German) at 105^{0}C for 24 h. All measurements were done in triplicate. The viscosity of HS was determined using vibro viscometer at 25^{0}C (Model SV-10, A&D Company Limited, Japan). All measurements were done in triplicate.

Steady shear and dynamic oscillatory measurements

Controlled-stress rheometer (AR 2000, TA Instruments, New Castle, DE, USA) was used to determine the dynamic rheological measurement of HS. The instrument is attached with computer software (Rheology Advantage Data Analysis Program, TA). A 40 mm parallel plate attachment with a gap of 1000 µm was used throughout the test. Sample was then placed at the bottom plate of the rheometer.

The dynamic stress sweep test was performed between 0.1 – 100 Pa at a constant frequency of 1 Hz to determine the linear viscoelastic region (LVE) response under oscillatory shear conditions. Then, the dynamic frequency sweep measurements under the selected linear viscoelastic response (LVE) with constant stress amplitude in the range of 0.01–10 Hz were performed. The measurements were carried out in duplicate using new samples.

Furthermore, the rheometer was set for the specified temperature and equilibrated for 10 minutes following with a programmed shear changing from 0.0003 to 100 1/s in 5 min to perform the steady shear flow measurement test. All measurements were performed at 25 ± 0.1^{0}C. Duplicate samples were used for each HS sample.

Texture analysis

Texture profile analysis (TPA) of the HS samples incorporated with PSC powder was performed with a Texture Analyzer- HD Plus (Stable Microsystem Surrey, UK) following Bourne (2002) procedures. The method used based on force during two site compression. The products were put in a specified container (50 mm in diameter) about 75% full. A 36 mm radius cylinder probe (P36) was used in the system. The parameters conditions applied in the test were load cell (5 kg), pre-test speed (1.50mm/s), test speed (2.00 mm/s) and post-test speed (2.00 mm/s). Then, a 25% compression of 15.00 mm compression distance was performed. Texture Expert program was used as the software connected to the computer for analyzing the data recorded from the present test. The following parameters were determined: firmness, viscosity, consistency and cohesiveness. All measurements were done in triplicate.

Statistical analysis

Experimental data obtained from pH, total solid content, viscosity and texture analysis measurements were subjected to statistical analyses using the commercial SPSS 20 computer program. Data were averaged and mean comparisons were performed using ANOVA and a Duncan Multiple Range Test at 95% confidence. All measurements were carried out in triplicate (n=3). The experiments were replicated twice.

Results and Discussion

Table 2. Physical characteristics of HS enriched with PSC powder

	A (0%)	B (20%)	C (40%)	D (60%)	E (80%)	F (100%)
pH	4.05±0.25^{a}	4.08±0.32^{a}	4.08±0.26^{a}	4.12±0.15^{a}	4.12±0.25^{a}	4.14±0.28^{a}
Total solid	41.32^{a}	39.54^{c}	39.55^{c}	38.15^{d}	40.00^{b}	37.23^{e}
Viscosity (Pa.s)	1.46^{d}	1.50^{d}	1.48^{d}	1.72^{c}	2.50^{b}	3.05^{a}
Firmness	120.00^{c}	177.32^{b}	173.13^{b}	173.65^{b}	176.92^{b}	232.67^{a}
Consistency	661.78^{c}	920.00^{b}	895.00^{b}	898.66^{b}	925.29^{b}	1162.61^{a}
Cohesiveness	-71.90^{a}	-114.17^{b}	-113.78^{b}	-112.71^{b}	-112.74^{b}	-147.56^{c}
Index of Viscosity	-336.70^{a}	-456.47^{b}	-456.93^{b}	-446.13^{b}	-458.71^{b}	-566.54^{c}

$^{a-d}$Mean values with different letters are statistically different ($p<0.05$)
(A=0% PSC, B=20% PSC, C= 40%PSC, D= 60% PSC, E=80% PSC, F=100%PSC

Results of pH, total solid and viscosity measurements on HS samples are given in Table 2. It can be seen that pH values of all HS were in the range of 4.05- 4.14 indicating an acidic characteristics. This characteristic certainly resulted from some citric acid within the formulation as shown in Table 1. Citric acid was added in the HS as acidity regulators, antimicrobial and as flavouring agents to provide sour flavour and to increase the acidity of the products (Majzoobi *et al*., 2003).

HS (A) was found to be the most acidic compared to the others as it does not contained PSC powder which is less acidic. The pH of PSC powder is in the range of 6.00 - 7.00. The low pH (6.1 - 7.2) and low titratable acid in the PSC powder further suggests why they may be edible (Khan *et al*., 2011). On the contrary, HS (F) was observed as least acidic Herbal seasoning. Besides, the product is still categorized under the high acid food as their pH is less than 4.5 (Codex Allimentarius, 2010).

TS was significantly different among HS (A) and no added coconut milk powder HS (F) in the product. Particularly, HS (F) supposes to possess the highest TS (Table 2). On the other hand, HS (A) was found the highest TS value and probably comes from the other ingredients available in the coconut milk powder. Meanwhile, the HS (F) only contain PSC powder with no added food additives. The viscosity of HS (A) and HS (F) are significantly different ($p<0.05$). However, HS (A), (B) and (D) were not significant ($p>0.05$) among other treatments.

The viscosity of HS (A)(1.46 Pa.s) was not

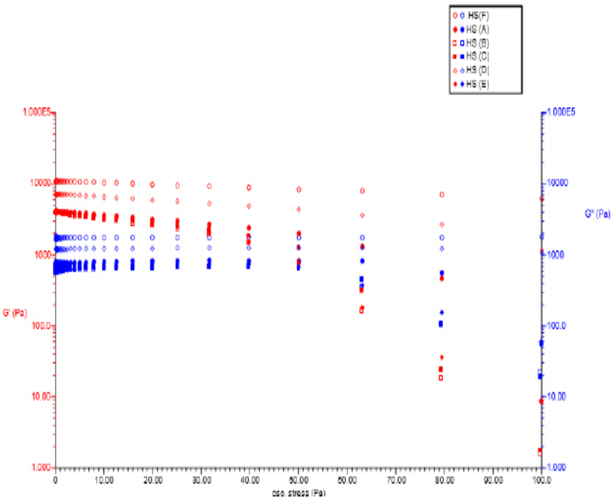

Figure 1. Amplitude sweep profiles for HS samples obtained at constant frequency of 1 Hz (a) HS (A) , (b) HS (B), (c) HS (C), (c) HS (D), (c) HS (E), and (d) HS (F).

significantly different (p>0.05) compared to HS (B)(1.50 Pa.s) and HS (C)(1.48 Pa.s). On the other hand, HS (D)(1.72 Pa.s) was significant different (p<0.05) with HS (E)(2.50 Pa.s). Meanwhile, HS (F) (2.50 Pa.s) recorded the most viscous product among the PSC-based HS. Viscosity is an important factor in herbal seasoning as it affects the functionality of the paste. Viscosity is also important criteria for food paste as it will determine the acceptance of consumers to the developed products. Basically consumers prefer products that easy to pour and well mixed in packaging materials. Viscosity is an important property of foods such as beverages which affected the mouth feel and texture of fluids (Yu *et al*., 2007). Basically, high fiber content in PSC influence the viscosity of the product. Previous study done by Aishah and Wan Rosli (2013) showed that total dietary fiber content (TDF) of PSC powder was 33.00 ± 1.53g/100g and it contains soluble fiber at 0.10 ± 0.00g/100g and insoluble fiber at 32.90 ± 0.35 g/100g. From the present findings, viscosity of HS is in line with the concentration of TDF content in HS (data not shown). It is speculated that higher viscosity in HS samples is correlated to higher fiber content in the PSC powder used.

The viscosity of HS (C)(1.48 Pa.s) was not coherent with PSC powder addition. This might be resulted from the added PSC powder which not sufficient to absorb the globules of fat the HS and also the equilibrium in the product was not sufficient. Mohamed et al. (2011) reported that the increasing concentration of fiber related to the increase in viscosity. The changes in viscosity subjected to temperature changes of dietary fiber solution. Moreover, heating may decrease the viscosity of the products since the process may rupture molecular entanglement and bonds may give strength to the molecular structure and reduce the effective molecular volume in protein and sugars. The reduction in viscosity related to shear rate was increased also associated to the increased alignment of constituent molecules of the tested system (Rha, 1975).

Stress sweep test

Stress sweep test was performed to find the linear viscoelastic region (LVE). G′ is in line to the extent of the elastic component as the result of its crosslinking, entanglement, or aggregation in the system. On the other aspect, G″ is rational to the extent of the viscous (liquid-like) characteristic of the system. Basically, All PSC-based HS showed G' greater than G'' over the frequency range studied (0-100 Pa). Under frequency range of 0.1 – 10Hz displayed G' > G'' value suggested that HS can be considered as gel-like networks. The stability of the system is showed by a wider LVE region that indicates more better resist the external stress. Based on stress sweep test, it showed that HS (A) had the shortest LVE region (Figure 1).

The present findings indicated that HS (A) which had the lowest stability only required the minimum stress for the structure deformation. On the other part, HS (F) demonstrated the widest LVE region (0-100 Pa) and certainly need the highest stress to deform their original structures. All PSC-based HS recorded higher G' compared to G'' (Figure 1).

Figure 2a displayed the magnitudes of both G' and G'' that increased with frequency. This implied that elastic modulus (G') was relatively not dependent of frequency whereas the viscous modulus (G'') was dependent on frequency. The weak gel formed in all the extract showed this type of behavior (Clark and Ross-Murphy, 1987). Rosalina and Bhattacharya (2002) also reported similar behavior of starch gel by using dynamic rheological measurement. The domination of elastic modulus (G' > G'') showing an elastic characteristic which give better stability during storage period and implying that at the frequencies tested, the paste behaved as a solid (Trigueros *et al*., 2012). According to linear viscoelastic conditions, higher G' that show the elastic modulus than the G'' that show loss modulus for all the samples, indicating that the PSC-based HS and ketchups exhibited as gels (Elena *et al*., 2008).

Dynamic frequency sweep test

Under the linear viscoelastic range (LVE), the dynamic frequency sweep tests were performed to determine the frequency dependence of the elastic and viscous modulus. Figure 2b illustrates the

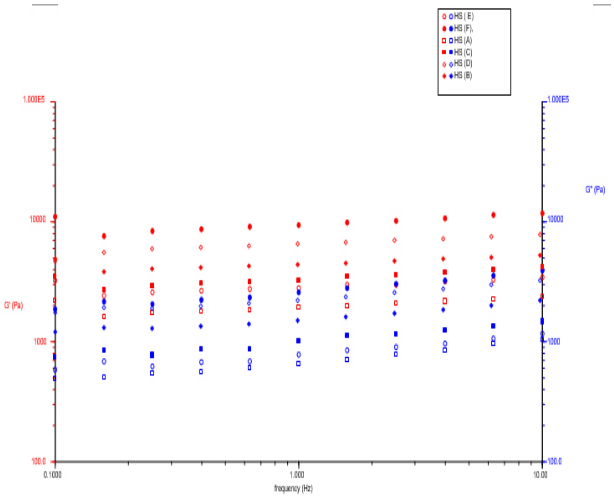

Figure 2a. Frequency sweep profiles of HS samples showing G′and G".

mechanical spectra showing the viscoelastic behavior of HS subjected to low-amplitude oscillatory deformation tests at 25⁰C. The stored potential energy that showed the predominant response of the sample to the imposed deformation, which characterized by elastic modulus, G', over the viscous modulus, G''. Moreover, HS behaved like an elastic solid and supported by phase angle values. Fasina *et al.*, (2003) displayed similar behavioral properties for restructured sweet potato puree. In addition, tomato paste and ketchup also behaved as gels (Elena *et al.*, 2008). Furthermore, based on the mechanical spectra, the network structure in HS (A) had the lowest value owing to the most frequency-sensitive G′ and the highest magnitude of tan δ (Figure 2b). HS (F) showed high firmness characteristics which are proven as their high G' value obtained from oscillation test in the rheology test for products. The tan δ of HS (F) in Figure 2b was lower compared with other samples indicates the samples were the most viscous compared to other treatments.

Oscillatory frequency sweeps test

Oscillatory frequency sweeps test shows the nature of the structuring mechanisms present in a fluid that was conducted under the LVR region of 0.1 to 10 Hz. During the test, HS was exposed to a small deformation oscillation that covers certain range of frequencies to assess the structural response to deformations of longer or shorter timescales. The phase angle (tan δ) gives ratio of G'' and G' measuring energy loss compared to energy stored. From the calculation indicates that a low value of phase angle (tan δ) shows the gel has predominant elastic character (more solid like).

Oscillation stress provides an easy way to interpret information about the semi solid rigidity and yield stress (gel strength) of HS added with PSC powder. In the oscillation sweep test, HS is subjected to small amplitude oscillatory shear. Initially, the stress given is low to retain the structure but as the test progresses the incrementing applied stress is given resulted in the disruption of structure.

Addition of 100% PSC powder in HS resulted in higher moduli values than others treatments including control. HS (F) also recorded the highest viscosity, followed by HS (E). In addition, HS (F) exhibits more permanent elasticity as compared to other treatments. The lowest moduli value was recorded by control samples which in agreement of the result viscosity from the texture profile analysis. The replacement of coconut milk powder with PSC powder resulted gradually increase in viscosity of HS that can be explained by the ratio between the viscous and elastic components (tan δ). Addition level of PSC powder into HS formulations resulted more elasticity to the HS. The present results are agreed with the finding of Ravindran and Matia (2009) who substituting starch with funegreek in soup. The phase angle data has confirmed the viscoelastic nature of the HS products. Viscosity plays import roles in determination the characteristic of the product. Some products will recover quickly in terms of their viscosities during processing or under shearing for instance mixing or filling while others will go on building viscosity slowly for hours, days or even weeks.

Viscosity profiling

HS added with PSC powder had a non-newtonian characteristics. The other examples of non-newtonian fluids are emulsion, gels and suspensions. Normally, the degree of shear exposed to the products determines their viscosity since the value is not fixed and shear thinning is the common characteristics for non-newtonian. The characteristic of shear thinning is the decreasing viscosity with increasing applied shear rate. Thus, the desirable attributes for a product is obtained such as the suspension stability at rest, while facilitate in pouring when a stress is applied.

Figure 3 shows the shear viscosity as a function of shear rate. During shear rate sweep, the lowest viscosity is shown by HS(A), while other remaining treatments show comparable in the level of viscosity. In particular, HS (F) had the most consistency which is the highest viscosity compared to other samples. The lowest content of total dietary fiber and the weakest network structure might contribute to the lowest viscosity of HS (A) among all samples studied in this work. Furthermore, rheological behavior shows by tomato paste is a non-newtonian, shear-thinning and time-dependent fluid that shows an apparent yield stress (Abu-Jdayil *et al.*, 2004).

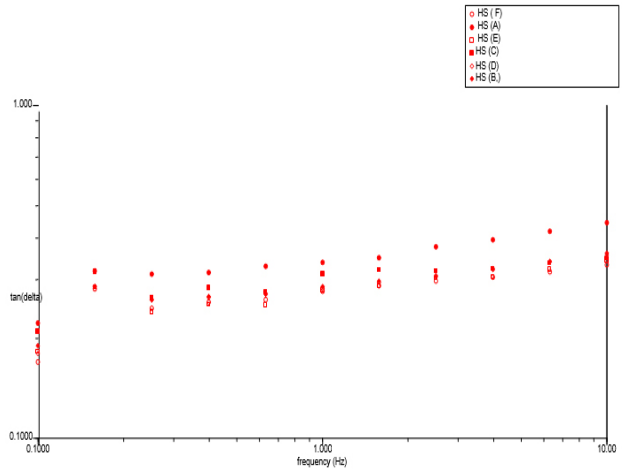

Figure 2b. Frequency sweep profiles of HS samples showing tan δ as a function of frequency within LVE region.

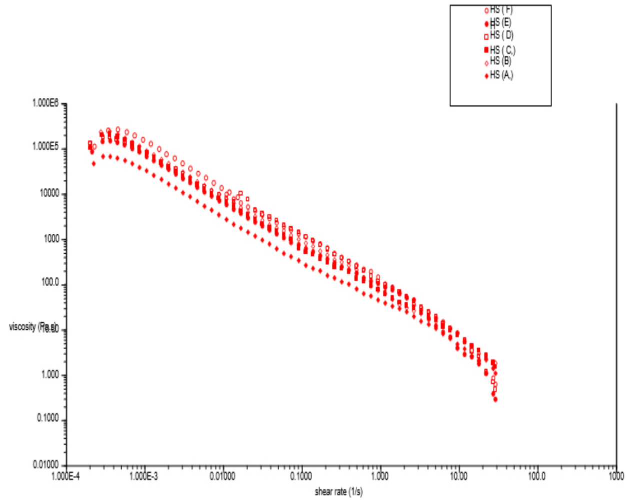

Figure 3. Shear viscosity as a function of shear rate for HS enriched with PSC powder.

Figure 3 shows the apparent viscosity for each mixture of coconut milk powder: PSC mixture over a shear rate range of 0.0003 – 100 1/s. As expected the shear rate sweeps results, the shear thinning behavior was detected in all samples. The paste shows a shear thinning profile starting at viscosity of around 100,000 Pa.s at a shear rate of 1 x 10^4 1/s and shearing down to 1 Pa.s at a shear rate of 100 1/s. Control sample recorded the lowest viscosity along the shear rate given to the sample compared to other remaining samples. HS (F) shows the highest in viscosity at the beginning and starts to become less solid at a shear rate of 10 1/s.

Increment in tan δ is demonstrated by a greater impact in the viscous portion of the final gel containing different level of PSC powder concentration. It is possibly that the presence of fat from crude coconut (6.3%) at fixed amount generally contributes to the development of final viscoelastic properties. Therefore, the fat droplets may be acting as active fillers which responsible to the formation of the final network. The application of shear thinning characteristics from the added PSC powder in the product is a full picture across a range of shear rate and is seen more meaningful if compare to only a single shear rate determination. From the flow curve, a viscosity relevant to the product processing and conditions can be known. The viscosity also rises with decreasing shear rate.

Texture

Texture is a key determinant of food quality. Therefore, the measurements using instrumental methods is important to study the characteristics of food products (Bourne, 2002). The early stage in developing the products is also associated with desirable or undesirable changes in texture (Foegeding *et al.*, 2011).Table 4 shows textural attributes, firmness, consistency, adhesiveness and index of viscosity of all HS samples. The texture of the product also affected by physico-chemical treatments to mushroom (Matser *et al*., 2000). All textural attributes show increasing trend in line with PSC powder added in HS formulations. All attributes were significantly higher ($p<0.05$) for the HS samples added with PSC powder than for the control. The viscosity shows no significant different ($p>0.05$) between HS (B), HS (C), HS (D) and HS (E). The viscosity value of all HS enriched with ground PSC powder was more viscous than control which the viscosity was more than -336 gs. HS (F) show significantly higher ($p<0.05$) firmness compared to other samples including control. Regarding this matter, it is speculated that the mixture of ingredients interrupts the texture of the products. The processing time also can be the main reason of the changes in textural attributes values found in the samples. From the recent observation, it showed that the values were higher in all HS-based PSC powder relative to control for these four textural parameters. However, the increment in product firmness and cohesiveness ($p <0.05$) was well observed when PSC powder was added at amount higher than 20%. Lin et al. (2008) was observed that PSC powder absorbed more water than did wheat flour. Addition of PSC powder in the HS is the main factor contributes to the gel structure which increases the high consistency properties of all analyzed samples. Generally, all texture profile analysis (TPA) attributes of PSC-based HS samples were influenced by the addition of PSC powder as shown in Figure 4.

The higher values of firmness indicate the solid like structure in HS or having a harder texture. The high firmness characteristics in HS (F) is proven as their high G' value obtained from oscillation test. The tan delta of HS (F) (Figure 2b) is lower compared with other samples indicates the samples are the most viscous. Index of viscosity is higher in all samples excluding control with the addition of mushroom powder. Gel structure formed from added mushroom powder is one of the main factors contributing to high consistency properties of all samples containing PSC powder.

Conclusion

HS were investigated in terms of their physical, textural and rheological properties. These HS showed acidic characteristic with pH in the range of 4.05–4.15. Furthermore, they could consist of coconut crude (kerisik) which was most likely added to enhance their flow characteristics. Rheological experiments showed that all studied HS had a weak gel-like characteristic (G′ > G″). Herbal seasoning (HS) exhibited viscoelastic behavior with G' much greater than G" at value frequency constant at 1 Hz. Study shear data supported oscillatory measurements and revealed that the semi solid samples exhibited shear thinning behavior. The backward rig texture analysis conducted confirms the viscosity and the material behaviors of the HS. The presence of coconut milk powder/ oyster mushroom powder mixture in the HS promoted their elastic properties. Furthermore, it was found that the HS without containing PSC powder had weak network structure and inferior flow properties.

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References

Abu-Jdayil, B., Banat, F., Jumah, R., Al-Asheh, S. and Hammad, S. 2004. A comparative study of rheological characteristics of tomato paste and tomato powder solutions. International Journal of Food Properties 7: 483–497.

Ahmed, J., Shivhare, U.S. and Raghavan. G.S.V. 2000. Rheological characteristics and kinetics of colour degradation of green chili puree. Journal of Food Engineering 44:239-244.

Aishah, M. S. and Wan Rosli, W. I. 2013. The effect of addition of oyster mushroom *(Pleurotus sajor-caju)* on nutrient composition and sensory acceptation of selected wheat- and rice-based products. International Food Research Journal 20(1): 183-188.

Bano, Z. and Rajarathnam, S. 1988. Pleurotus mushrooms, Part II: Chemical composition, nutritional value, post-harvest physiology, preservation and roll as human food. C.R.C. Critical Reviews in Food Science and Nutrition 27(2): 87-158.

Bourne, M. C. 2002. Food texture and viscosity: Concept and measurement. 2nd ed. London, UK: Academic Press.

Burton, K. S. and Noble, R. 1993. The influence of flush number, bruising and storage temperature on mushroom quality. Postharvest Biology and Technology 31(1): 39–47.

Clark, A. H. and Ross-Murphy, S. B. 1987. Structural and mechanical properties of biopolymer gels. Advance Polymer Science 83: 57–192.

Codex Alimentarius Commision. 2010. Report of the 31st session of the Codex Committee on nutrition and foods for specific dietary uses, Codex alimentarius. Rome: Food and Agriculture Organization of the United Nations

Elena, B., Ene Pilma W. and Eva, T. 2008. Rheological and structural characterization of tomato paste and its influence on the quality of ketchup. LWT- Food Science and Technology 41: 1289–1300.

Fasina, O. O., Walter, W. M., Fleming, H. P. and Simunovic, N. 2003. Viscoelastic properties of restructured sweet potato puree. International Journal of Food Science and Technology 38: 421–425.

Foegeding, E. A., Daubert, C. R., Drake, M. A., Essick, G., Trulsson, M. and Vinyard, C. J. 2011. A comprehensive approach to understanding textural properties of semi- and soft-solid foods. Journal of Texture Studies 42: 103-129.

Fukushima M. 2000. LDL receptor mRNA in rats is increased by dietary mushroom *(Agarics bisporus)* fibre and sugar beef fibre. Journal of Nutrition 130: 2151-2156.

Kalac, P. 2009. Chemical composition and nutritional value of European species of wild growing mushrooms: A review. Food Chemistry 113: 9–16.

Khan, S.M., A. Nawaz, W. Malik, N. Javed, T. Yasmin, M. Rehman, A. Qayyum, Q. Iqbal, T. Ahmad and A.A. Khan. 2011. Morphological and molecular characterization of Oyster mushroom (*Pleurotus* spp.). African Journal of Biotechnology 10: 2638-2643.

Kumar, A., Singh M. and Singh, G. 2011. Effect of different pretreatments on the quality of mushrooms during solar drying. Journal of Food science and Technology DOI 10.1007/s13197-011- 0320-5.

Lin, L.Y., Tseng, Y. Li, R, C. and Mau, J. L. 2008. Quality of shiitake stipe bread. Journal of Food Processing and Preservation 32: 1002-1015.

Manzi, P., Marconi, S., Guzzi, A. and Pizzoferrato, L. 2004. Commercial mushrooms: nutritional quality and effect of cooking. Food Chemistry 84: 201-206.

Majzoobi, M., Rowe, A. J., Connock, M., Hill, S. E. and Harding, S. E. 2003. Partial fractionation of wheat starch amylose and amylopectin using analytical ultracentrifugation. Carbohydrate Polymers 52: 269–274.

Matser, A. M., Knott E. R., Teunissen, P.G.M. and Bartels, P.V. 2000. Effects of high isostatic pressure on mushroom. Journals of Food Engineering 45(1): 11-16.

Mattila, P., Salo-Vaananen, P., Konko, K., Aro, H. and Jalava, T. 2002. Basic Composition and Amino Acid Contents of Mushrooms Cultivated in Finland. Journal of Agricultural Food Chemistry 50: 6419-6422.

Mohamed, E., Dorothea, B., Olivier, R., Souhail, B., Christophe, B. and Hamadi, A. 2011. Dietary fibre and fibre-rich by-products of food processing: Characterization, technological functionality and commercial applications: A review, Food Chemistry 124: 411–421.

Ngai, P. H. K. and Ng, T. B. 2004. A ribonuclease with antimicrobial, antimitogenic and antiproliferative activities from the edible mushroom Pleurotus sajor-caju. Peptides 25: 11- 17.

Nnorom, I. C., Jarzynska, G., Falandysz, J., Drewnowska, M., Okoye, I.and Oji-Nnorom, C. G. 2012. Occurrence and accumulation of mercury in two species of wild grown Pleurotus mushrooms from Southeastern Nigeria. Ecotoxicology and Environmental Safety 84: 78-83.

Rao, M. A. and Steffe, J. F. 1992. Viscoelastic properties of foods. NY, USA: Elsevier Applied Science.

Ravindran, L. and Matia-Merino. L. 2009. "Starch-Fenugreek *(Trigonella foenum-graecum*L.) Polysaccharide Interactions in Pure and Soup Systems. Food Hydrocolloids 23: 1047-1053.

Rha, C. 1975. Theories and principles of viscosity. In : C. Rha (ed). Theory determination and control of physical properties of food materials. Reidel, Dordrecht-Holland, pp. 7-24.

Rosalina, I. and Bhattacharya, M. 2002. Dynamic rheological measurements and analysis of starch gels. Carbohydrate Polymers 48: 191–202.

Silva, S.O., Costa, S.M.G. and Clemente, E. 2002. Chemical composition of Pleurotus pulmonaris (Fr.) Que´l, substrates and residues after cultivation. Brazilian Archives of Biology and Technology 45: 531–535.

Sloan, E. 2005. With better-for-you menu options, fresh fast fixin's, and heart friendly foods, the global food industry retools for health. Top 10 Global Food Trends. Food Technology 59(4): 20-32.

Trigueros, E. Sayas-Barbera, J.A. Perez-Alvarez and Sendra, E. 2012. Use of date blanching water for reconstituting milk powder: Yogurt manufacture. Food and Bioproducts Processing 90: 506-514.

Wan Rosli, W.I., Solihah, M.A., Aishah, M., Nik Fakurudin, N.A. and Mohsin, S.S.J. 2011. Colour, textural properties, cooking characteristics and fibre content of chicken patty added with oyster mushroom *(Pleurotus sajor-caju)*: International Food Research Journal 18: 612-618.

Wan Rosli, W. I. and Solihah, M. A. 2012. Effect on the addition of Pleurotus sajor-caju (PSC) on physical and sensorial properties of beef patty. International Food Research Journal 19 (3): 993-999.

Wan Rosli, W. I., Nurhanan, A.R. and Aishah, M.S. 2012. Effect of Partial Replacement of Wheat Flour with Oyster Mushroom *(Pleurotus sajor-caju)* Powder on Nutritional Composition and Sensory Properties of Butter Biscuit. Sains Malaysiana 41(12): 1565–1570.

Weaver, C. and Marr, E.T. 2013. White vegetables: a forgotten source of nutrients: Purdue roundtable executive summary. Advances in Nutrition 4: 318-326.

Yu, J., Ahmedna, M. and Goktepe, I. 2007. Peanut protein concentrate: production and functional properties as affected by processing. Food Chemistry 103(1):121-129.