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# The Effect of Thermal Treatments on the Rheological Behavior of Basil Seed (*Ocimum basilicum*) and Balangu Seed (*Lallemantia royleana*) Gums

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ABSTRACT: The objective of this study was to investigate the effect of different thermal treatments (20-100°C at five levels for 20 min) on rheological properties of basil seed (*Ocimum basilicum*) and balangu seed (*Lallemantia royleana*) gums. Power law model well described the non-Newtonian pseudoplastic behaviour of the seeds gums. The apparent viscosity of balangu seed gum was dramatically affected by the temperature and decreased from 0.015 to 0.007 Pa.s with increasing temperature from 20 to 100°C (at 97.8 $s^{-1}$). Apparent viscosity of basil seed gum decreased from 0.053 to 0.022 Pa.s with increasing temperature from 20 to 100°C (shear rate=97.8 $s^{-1}$). Seeds gums showed shear thinning behavior at all temperatures. The Arrhenius relationship was used to describe the temperature dependency of rheological parameters of basil seed and balangu seed gums. The activation energy of basil seed and balangu seed gums was quantified using an Arrhenius equation and increased from 4297 to 17434 J $mol^{-1}$ and 2210 to 11257 J $mol^{-1}$ as shear rate changed from 6.12 to 245 $s^{-1}$, respectively. The flow behavior index (n), that is related to non-Newtonian behavior (pseudoplasticity), increased significantly ($P \le 0.05$) in basil seed gum after heating, however it was decreased significantly ($P \le 0.05$) in balangu seed gum after heating.

**Keywords**: *Balangu Seed, Basil Seed, Hydrocolloid, Rheology, Temperature*.

## Introduction

Thermal process design such as pasteurization, sterilization, evaporation, cooking, baking and drying for liquid foods requires accurate information on the flow behavior to arrive at processing conditions that ensure the safety and improve the quality (Marcotte *et al*., 2001b). In these continuous processes, rheological properties play a major role describing the heat transfer of the treatment, (Maciel *et al*., 2005; Moser *et al*., 2013).

Hydrocolloids are used to confer stability to the products undergoing high temperatures. They are water-soluble, high-molecular weight biopolymers that create varieties of functions in food and pharmaceutical systems such as enhancing viscosity, creating gel-structures formation of a film, control of crystallization, inhibition of syneresis, improving texture, encapsulation of flavors and lengthening the physical stability (Sánchez *et al*., 1995; Sahin and Ozdemir, 2004; Dickinson, 2009).

Among commercial gums, the hydrocolloids derived from seeds are still used extremely in food formulations as

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thickeners in dressings, sauces and frozen products because of their cold water dispersibility, compatibility with high acidic emulsions because of their appropriate price, easy availability and proper functionality. In addition by increasing the viscosity the texture is modified, inhibit ice crystal formation and control the product consistency with respect to changes in the temperature (Salehi *et al*., 2015).

According to the increasing demand for hydrocolloids with specific functionality in the recent years, finding new hydrocolloid sources with appropriate properties is an active area of studies. Basil seed (*Ocimum basilicum L.*) is a member of genus *Ocimum*. The genus *Ocimum* is comprised between 50 to 150 species of herbs and shrubs. Basil seed is cultivated in large quantities in the tropical regions of Asia, Africa and Central and South America. This seed has reasonable amounts of gum with good functional properties which is comparable to commercial food hydrocolloids (Salehi *et al*., 2015). Some potential of the basil seed gum as a new source of hydrocolloid have been recently investigated by Salehi *et al*. (2015).

Balangu seed (*Lallemantia royleana*) is a folk medicinal plant of Labiatae family, that grows naturally in Asia, Europe, and Middle East (Naghibi *et al*., 2005). The Effect of sugars and salts on rheological properties of Balangu seed gum as a new potential source of hydrocolloid has been investigated by Salehi *et al*. (2014).

Research concerned with the rheological properties related to the stability at high temperatures is essential to determine the capability of hydrocolloid used in food formulations. Therefore, the objective of this study is to investigate and compare the rheological attributes of basil seed and balangu seed gums under different temperatures and thermal treatments. In addition, the Arrhenius relationship has been used to describe the temperature dependency of the rheological parameters.

## Materials and Methods

- *Seeds gums*

Basil and balangu seeds were purchased from a local market in Gorgan, Iran. The cleaned basil and balangu seeds were soaked in distilled water to obtain the seed ratio of 20:1 at 50°C and pH of 7 for 20 min (Salehi *et al*., 2015). Separation of the gum from the swollen seeds was achieved by passing the seeds through an extractor equipped with a rotating plate that scraped the gum layer on the seed surface. The extracted solution was then filtered and dried in an air forced oven at 50°C (convection oven, Memmert Universal, Schwabach, Germany) and finally the powder was milled, packed and kept at cool and dry condition (Zameni *et al*., 2015; Salehi and Kashaninejad, 2015).

- *Sample preparation*

Basil seed and balangu seed gums solutions, 1% (w/w), were prepared by dispersing the gum powder in distilled water (magnetic stirrer, Falc Stirrer, UK). The solutions were kept in mixer (Memmert Universal, Schwabach, Germany) for 24 hours to complete hydration, for evaluation of shear rate dependency.

- *Rheological measurements*

To obtain information on the changes occurring during thermal processing, viscosities have been measured using a rotational viscometer (Model RVDV-II, Brookfield, Inc. USA) (Ramzi *et al*., 2015). Sample solutions were loaded into the cylindrical chamber (16 ml capacity; ULA-31Y, Brookfield, Inc. USA) for all experiments and were allowed to equilibrate at the desired temperature using a circulating water jacket (Model ULA-40Y, Brookfield, Inc. USA). The rheological parameters of basil seed and balangu seed gums at different temperatures (20, 40, 60, 80 and

100ºC, ± 0.1ºC) were studied using spindle YULA-15 at logarithmic shear rate of 6.12 to 245 1/s.

- *Thermal treatments*

In order to study the effect of heat treatment on the rheological properties of basil seed and balangu seed gums, the solutions were poured into chamber (a radius of 3 cm and a height of 10 cm) and heat effects were evaluated at five different temperatures (20, 40, 60, 80 and 100°C) for 20 min. All the thermal treatments were conducted in water bath (Memmert Universal, Schwabach, Germany). The gums solutions were cooled to 20°C before rheological experiments.

- *Shear rate dependency*

The shear rate ($\dot{\gamma}$) dependency of steady shear rheological properties of gums solutions might be described by different flow models such as Power law, Herschel–Bulkley and Casson models. As the Power law model (Eq.1) gave the best fit with basil seed and balangu seed gums solutions (Salehi *et al*., 2014; Zameni *et al*., 2015; Salehi and Kashaninejad, 2015), it was used to describe their flow behavior:

$$\tau = k\dot{\gamma}^{n} \tag{1}$$

Where, τ is shear stress (Pa), $\dot{\gamma}$ is the shear rate ($s^1$), k is the consistency coefficient ($Pa.s^n$) and n is the flow behavior index (dimensionless).

The effect of temperature on the viscosity of gum solutions must be known, as in most continuous heating processes, they will be subjected to a range of temperatures. In this study, an Arrhenius equation (Eq. 2) was used to compare changes in apparent viscosity of selected hydrocolloids at different temperatures:

$$\mu = \mu_0 \exp(-E_a / RT) \tag{2}$$

Where μ is the viscosity (Pa s), $\mu_0$ is a constant, $E_a$ is the activation energy (J $mol^{-1}$), T the absolute temperature (Kelvin) and R is the universal gas constant (8.314 J $mol^{-1}$ $K^{-1}$). Modeling of data was performed with non-linear and multiple regression analysis functions and parameters associated with different models estimated from the experimental data using Curve Expert program version 1.34 (Microsoft Corporation).

All experiments were conducted at two replications and the data was presented as a mean of each experiment. The data was statistically analyzed and mean comparisons were performed using Duncan multiple range test (SAS software 9.1.3, SAS institute, Inc., Cary, NC, USA).

## Results and Discussion

-*The effect of temperature on the rheological properties*

Thermal stability studies of polysaccharides, its derivatives and blends have been investigated and provide information on the applications of these materials as films, adhesives and coating and also in the pharmaceutical and food formulations (Maciel *et al*., 2005). The flow curves of basil gum solution at different concentrations and temperatures are presented in Figures 1 and 2, respectively. A clear pseudoplastic behavior has been observed at all concentrations and temperatures.

Apparent viscosity significantly decreased from 0.053 to 0.022 Pa.s with increasing temperature from 20 to 100°C (shear rate=97.8 $s^{-1}$) ($P<0.05$). Solutions of basil seed gum exhibited interesting pseudoplastic behavior with a rapid decrease in viscosity and increases in shear rate (from 5–60 $s^{-1}$) but less rapid at higher shear rate range (from 60–245 $s^{-1}$) across all temperatures. A high shear thinning behavior of polysaccharides allows liquid foods to be pumped easily and imparts a thinner consistency during swallowing (Vardhanabhuti and Ikeda, 2006). The presence of a high pseudoplastic behavior of basil seed gum could qualify it as a good stabilizers in some food formulations such as mayonnaise and salad dressing. Rheological parameters obtained using Power law model from basil seed and balangu seed gum solutions at temperatures between 20 and 100°C are presented in Table 1. It can be found that all samples represented shear thinning behavior; characterized by n values less than 1 at all thermal treatments. For all basil seed gum solutions, flow behavior index (n) decreased (increasing in pseudoplacticity), with increasing solution temperature.

The viscosity of gum solutions can be affected by variables such as concentration, temperature and shear rate. Shear rate dependency of the apparent viscosity of balangu seed gum solutions at different concentrations and temperatures are presented in Figures 3 and 4, respectively. The apparent viscosity of balangu seed gum was dramatically affected by the temperature, therefore a decrease was observed with increasing temperature. Balangu seed gum solutions showed stronger shear thinning behavior than basil seed gum solutions and K decreased with increasing solution temperature (Table 1). However, n did not follow an obvious trend in the apparent viscosity curves with the temperature. It is well acknowledged that high viscosity of food hydrocolloid is one of the most important request for food industry, and, therefore, basil seed and balangu seed gums could be an interesting and promising thickener.

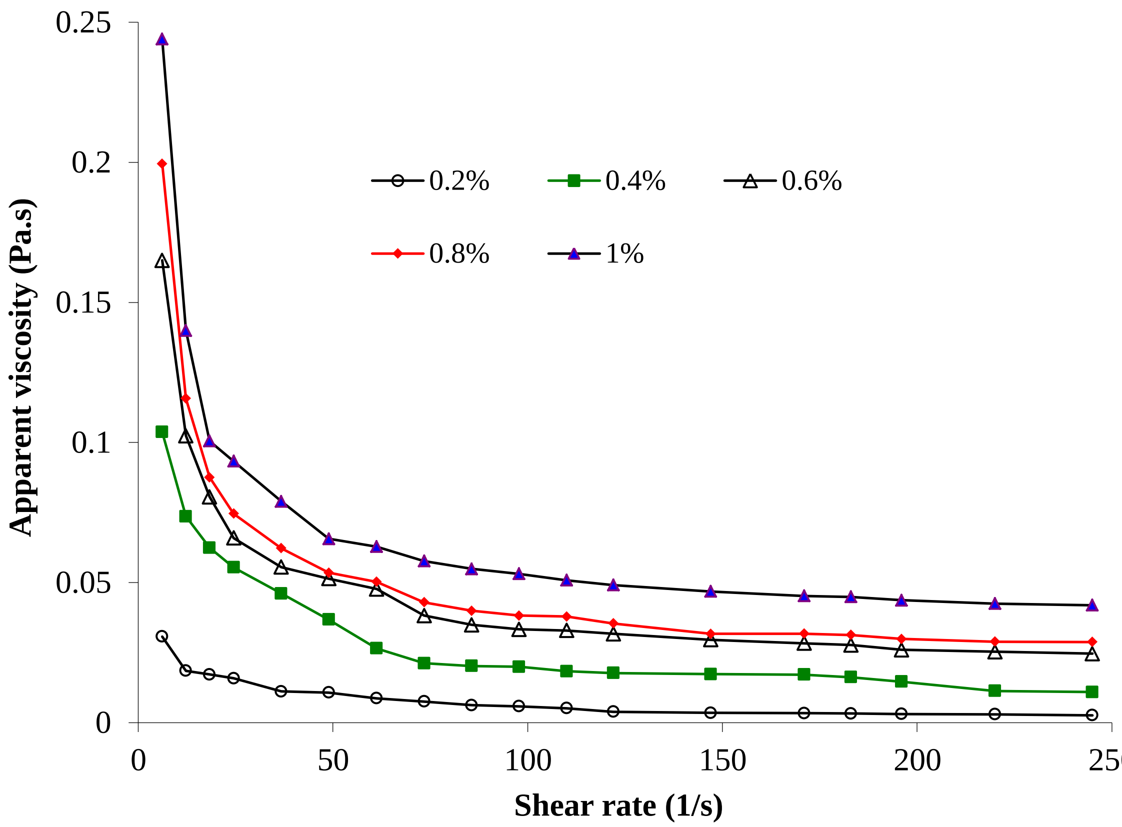


**Fig. 1.** The effect of different concentrations on apparent viscosity of basil seed gum solution.

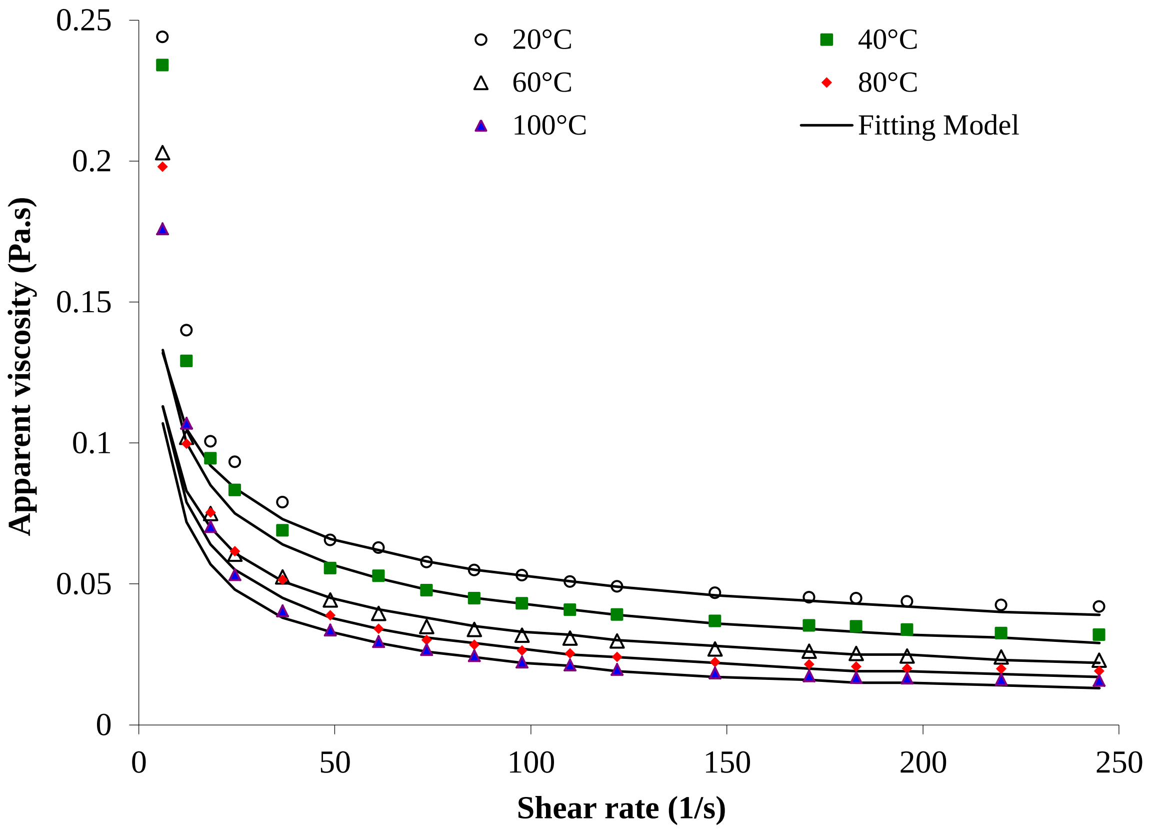


**Fig. 2.** The effect of different temperatures on apparent viscosity of basil seed gum solution, experimental and the predicted values.

**Table 1.** The rheological parameters of Power law model obtained for basil seed and balangu seed gums solutions at different temperatures*

| Temperature | Basil seed gum | | | Balangu seed gum | | |
|---|---|---|---|---|---|---|
| | K ($Pa.s^n$) | n | R | K ($Pa.s^n$) | n | R |
| 20°C | 0.24[c] | 0.67[a] | 0.997 | 0.22[a] | 0.42[b] | 0.987 |
| 40°C | 0.28[ab] | 0.59[b] | 0.994 | 0.15[b] | 0.45[ab] | 0.990 |
| 60°C | 0.25[bc] | 0.56[b] | 0.992 | 0.14[b] | 0.43[ab] | 0.993 |
| 80°C | 0.29[a] | 0.48[c] | 0.984 | 0.09[c] | 0.46[a] | 0.991 |
| 100°C | 0.30[a] | 0.43[d] | 0.962 | 0.08[c] | 0.42[b] | 0.993 |

* Means in a column followed by the different superscripts are significantly different at $p \leq 0.05$.

Apparent viscosity of Basil seed gum and Balangu seed gum solutions (1 % w/w) as a function of shear rate are shown in Figure 5. Because of continuous dependence of the viscosity of gum solutions on temperature, a linear relationship between log viscosity and the reciprocal of absolute temperature can be obtained.

The effect of thermal and freezing treatments on textural properties of basil seed gum was studied by Zameni *et al.* (2015). Hardness, adhesiveness and consistency of basil seed gel for the control sample were 13.5 g, 16.79 g.s , 52.59 g.s, respectively and all increased after thermal treatments. The results revealed that basil

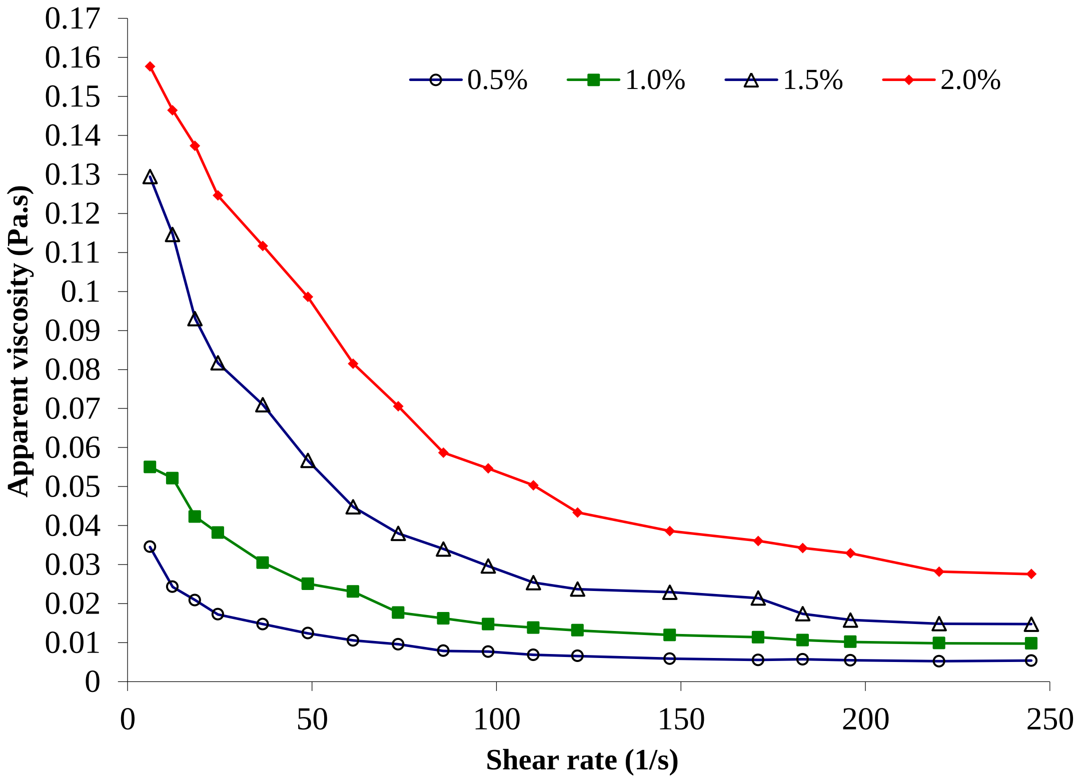


**Fig. 3.** The effect of different concentrations on apparent viscosity of balangu seed gum solution.

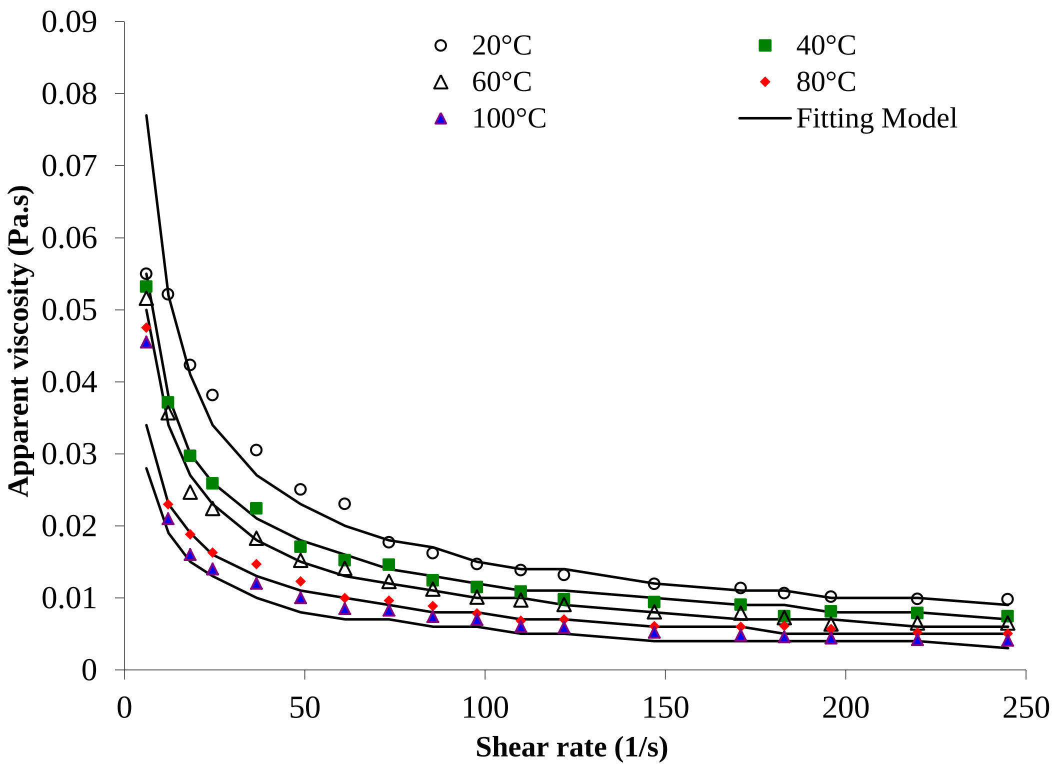


**Fig. 4.** The effect of different temperatures on apparent viscosity of balangu seed gum solution, experimental and the predicted values.

seed gum has the excellent ability to stand against heat treatment and the highest hardness, adhesiveness and consistency value of gum gels were observed in the sample treated at 121ºC for 20 min. Therefore it is possible to apply the Arrhenius equation to the data concerned with the viscosity of seed gum solution. The apparent viscosities of basil seed and balangu seed gums solutions at the temperatures of 20, 40, 60, 80 and 100°C followed an Arrhenius type model (Figures 6 and7). Parameters of Arrhenius model including Arrhenius constant ($\mu_0$), activation energies ($E_a$) and coefficients of determination ($R^2$) at different shear rate are presented in Table 2. The amount of $\mu_0$, for basil seed gum, decreased from $426.4\times10^{-4}$ Pa.s to $0.3\times10^{-4}$ Pa.s as the shear rate increased from 6.12 to 245 $s^{-1}$. A decrease in the activation energy is always associated with an increase in the shear rate (Marcotte *et al.*, 2001b). An increase in the activation energy was also observed by increasing the shear rate from 6.12 to 245 $s^{-1}$. Carrageenan solutions, which only denoted the yield stresses at 20°C and 40°C, showed the highest level of activation energies indicating a lower resistance at elevated temperatures. Activation energies ranged from 55 kJ/mole with $R^2$=0.95, 49 kJ/mole with $R^2$=0.95 and 45 kJ/mole with $R^2$=0.95 at 100, 200 and 300 $s^{-1}$, respectively (Marcotte *et al.*, 2001b). The Arrhenius equation has been successfully used to predict temperature dependence of sugar-rich liquid foods such as Indian tamamrind juice concentrates (Manohar *et al.*, 1991).

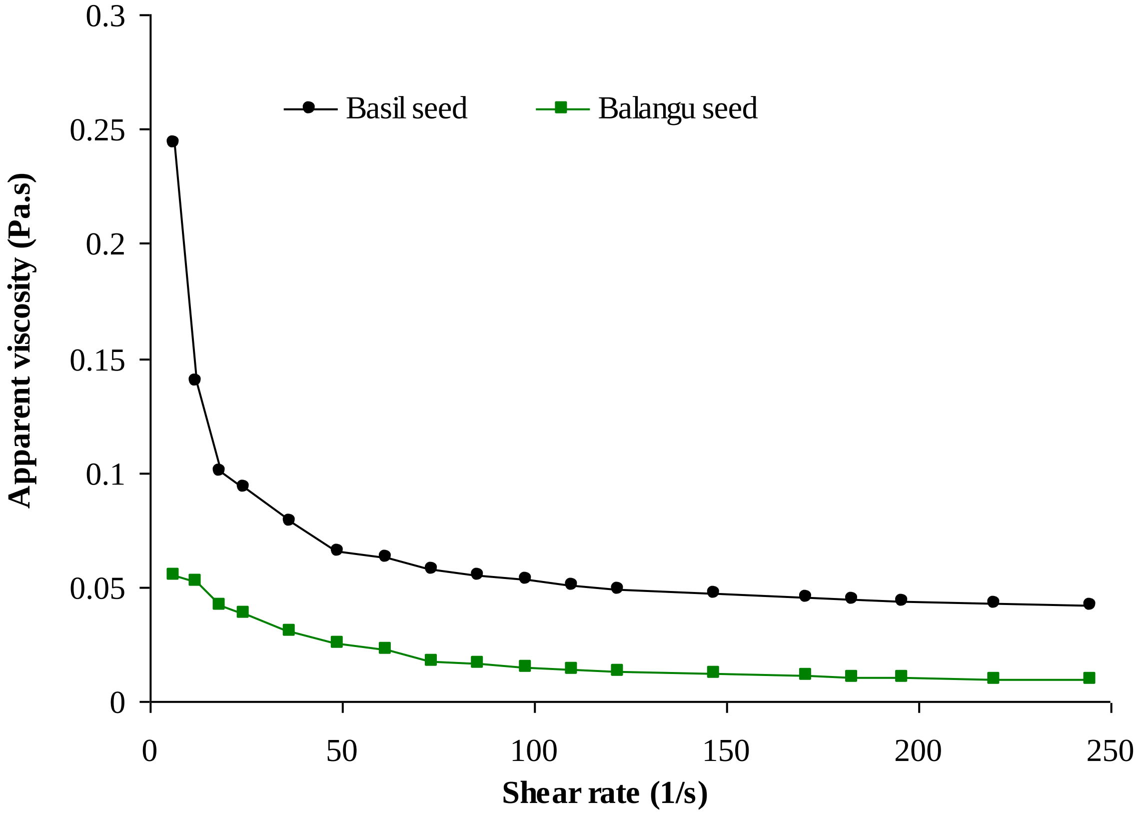


**Fig. 5.** Apparent viscosity of Basil seed gum and Balangu seed gum solutions (1 % w/w) as a function of shear rate.

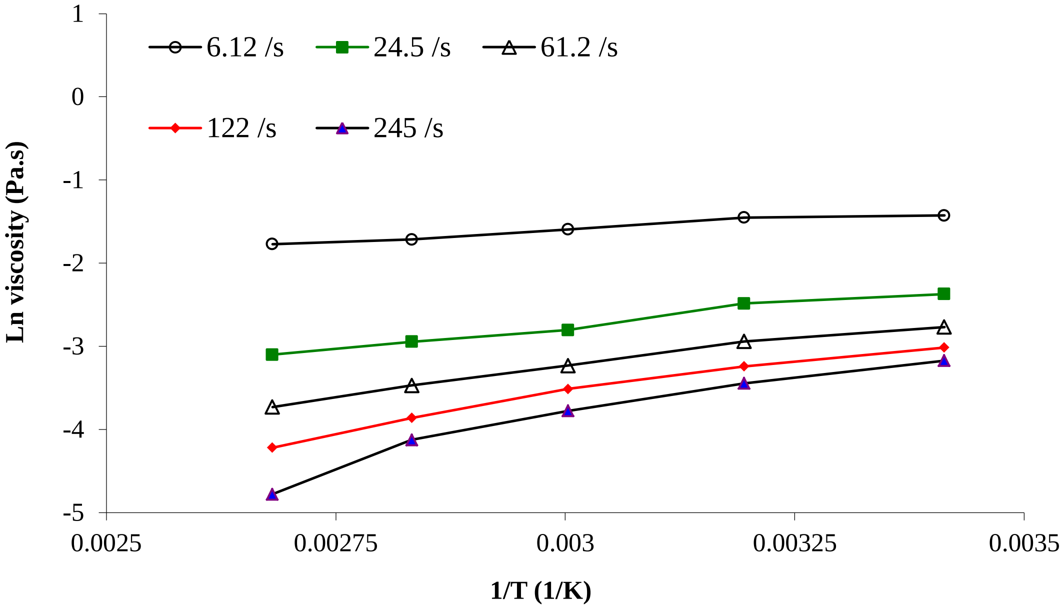


**Fig. 6.** Temperature dependency of the viscosity of basil seed gum solutions at different shear rates.

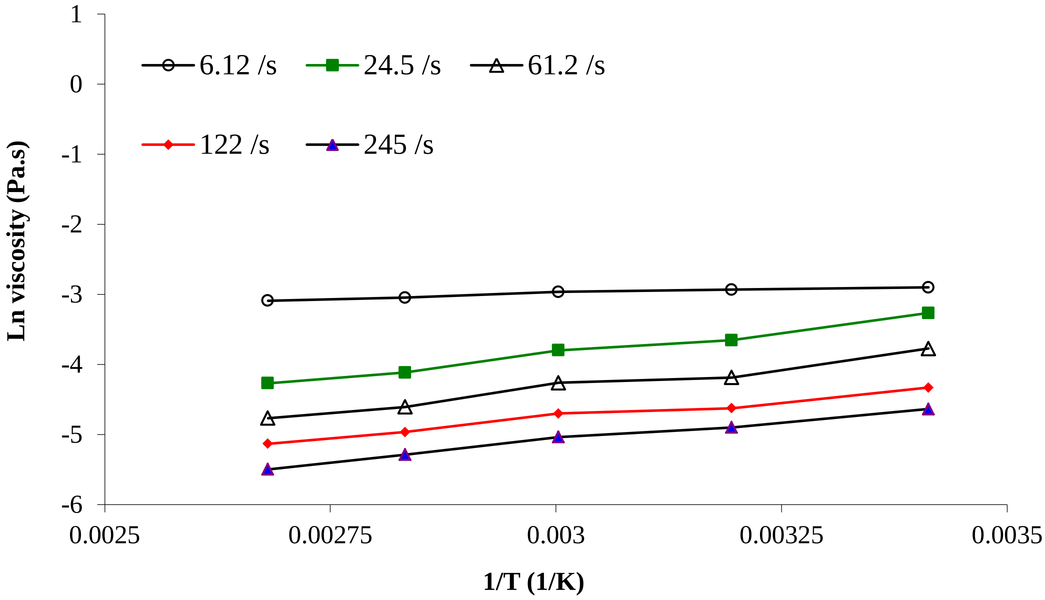


**Fig. 7.** Temperature dependency of the viscosity of the balangu seed gum solutions at different shear rates.

**Table 2.** Temperature dependency of apparent viscosity for different shear rate of basil seed and balangu seed gums solutions.

| Shear rate (1/s) | Basil seed gum | | | Balangu seed gum | | |
|---|---|---|---|---|---|---|
| | $\mu_0$ (Pa.s) | $E_a$ (J mol$^{-1}$) | $R^2$ | $\mu_0$ (Pa.s) | $E_a$ (J mol$^{-1}$) | $R^2$ |
| 6.12 | $426.4\times10^{-4}$ | 4297.5 | 0.95 | $225.7\times10^{-4}$ | 2210.7 | 0.95 |
| 24.5 | $27.1\times10^{-4}$ | 8713.1 | 0.98 | $3.7\times10^{-4}$ | 11257.2 | 0.99 |
| 61.2 | $7.1\times10^{-4}$ | 11074.2 | 0.98 | $2.4\times10^{-4}$ | 10991.1 | 0.97 |
| 122 | $2.0\times10^{-4}$ | 13634.9 | 0.97 | $3.5\times10^{-4}$ | 8812.8 | 0.98 |
| 245 | $0.3\times10^{-4}$ | 17434.4 | 0.94 | $1.9\times10^{-4}$ | 9552.8 | 0.99 |

The magnitude of $E_a$ for balangu seed gum solutions increased from 2210.7 to 11257.2 $Jmol^{-1}$ as shear rate increased from 6.12 to 245 $s^{-1}$. However, increasing the shear rate from 24.5 to 245 $s^{-1}$ decreased the activation energy.

As shown in the Figures 6 and 7, the slope values ($E_a$/R) of fitted lines were relatively low at all shear rates which is related to low activation energy of basil seed and balangu seed gums. Low values of activation energy imply that the seeds gums can maintain its viscosity at higher temperatures (Marcotte *et al*., 2001a). The activation energy of xanthan gum (1%) was reported 5740 J/mol by Marcotte *et al*. (2001a).

- *The effect of thermal treatment on the rheological properties*

During many thermal processes of food, gums are subjected to high temperatures. The effect of heat treatment on apparent viscosity of basil seed and balangu seed gums solutions are presented in Figures 8 and 9, respectively. It is clear that the apparent viscosity was decreased as the shear rate increased at all thermal conditions, indicating non-Newtonian shear thinning behavior. The rheological model parameters obtained by fitting the shear stress-shear rate data of basil seed and balangu seed gums after thermal treatment (20, 40, 60, 80 and 100°C-20 min) are summarized in Table 3. There were not significant differences between the consistency coefficient values of basil seed gum solutions after thermal treatment.

The flow behavior index (n), which is related to non-Newtonian behavior (pseudoplasticity), increased significantly ($P \le 0.05$) in basil seed gum after heating, however it was decreased significantly ($P \le 0.05$) in balangu seed gum after heating.

An increase in the flow behavior index (n) with thermal treatment indicates that the gum becomes less pseudoplastic especially at low shear rates (Vardhanabhuti and Ikeda, 2006). An increase in n value leads to slimy feel in the mouth. When an appropriate mouth feel properties for heat treated food are desired, low n value gums are excellent choices (Szczesniak and Farkas, 1962).

When the samples were heated, basil seed gum would have the ability to stand against heat treatment and its pseudoplasticity is decreased, where as increasing the thermal treatments led to increase in balangu seed gum pseudoplasticity. These results make basil seed gum a very promising ingredient in food formulation with a good heat stability similar to xanthan and guar gums (Downey, 2002).

Nevertheless, heat treatment did not have an obvious impact on consistency coefficient (k), which is related to viscosity of basil seed and balangu seed gums ($p \le 0.05$). Yamazaki et al. (2009) reported that heating of *Corchorus olitorius L.* solution at 60°C for 30 minutes leads to an increase in the viscosity of the solution. However, they reported lower viscosity at higher temperatures.

Glicksman (1982) reported similar reductions in xanthan solutions in distilled water after heating (115°C-30 min) and indicated that xanthan solution (1%) containing 0.1 %NaCl has viscosity loss of less than 10%.

## Conclusion

Foods are generally subjected to thermal treatments during processing operations such as pasteurization, sterilization, evaporation, cooking, baking and drying, that affect the functional properties of hydrocolloid solutions. Basil seed and balangu seed gums are new sources of hydrocolloids that exhibit desirable rheological properties. Steady shear flow behavior of basil seed and balangu seed gums were investigated at temperatures of 20–100°C. It indicated shear thinning behavior at all temperatures. The Power law model was found to be the most

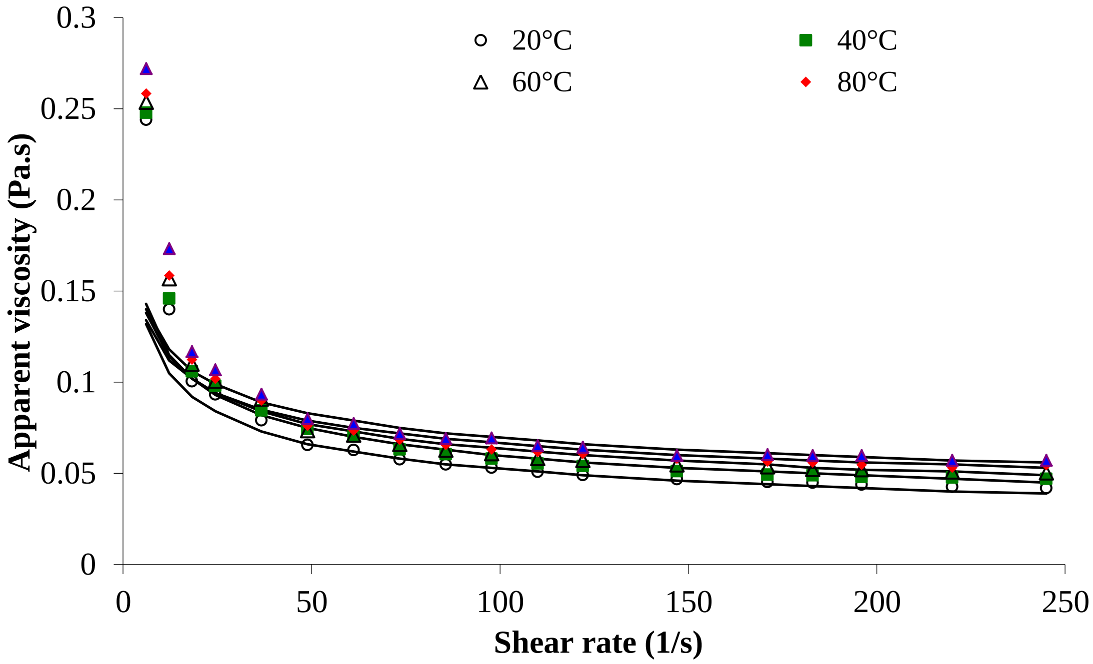


**Fig. 8.** The effect of heat treatment on apparent viscosity of basil seed gum solution, experimental and the predicted values.

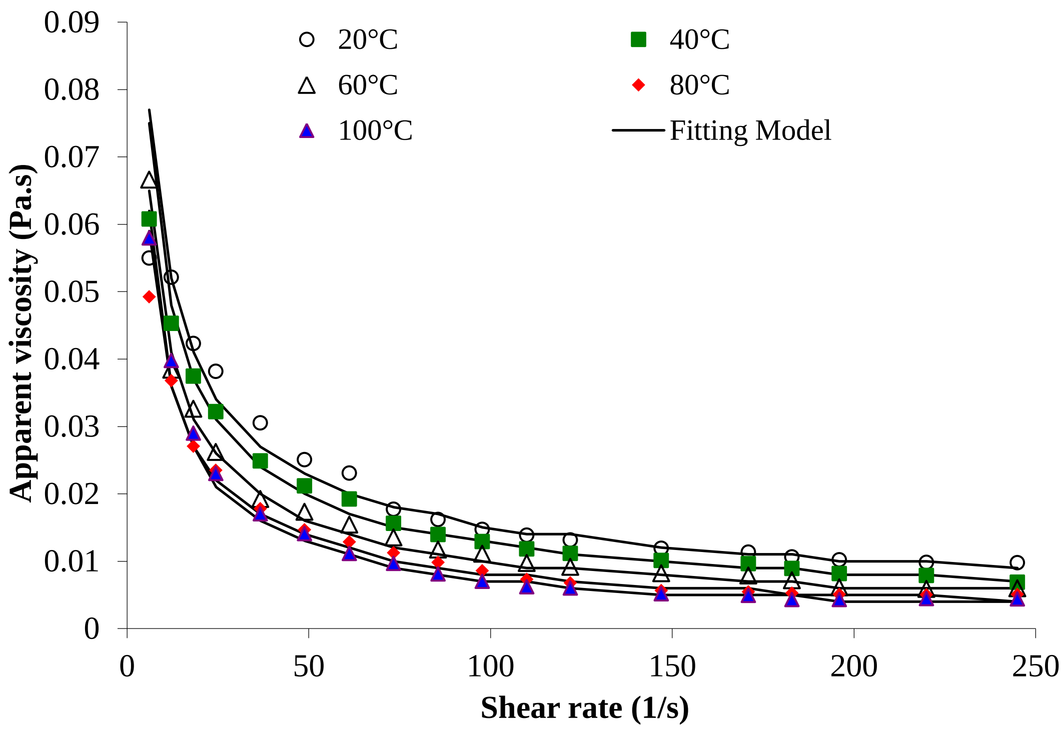


**Fig. 9.** The effect of heat treatment on apparent viscosity of balangu seed gum solution, experimental and the predicted values.

**Table 3.** The rheological parameters of Power law model obtained for Basil seed and Balangu seed gums solutions at different thermal conditions*

| Treatment (20 min) | Power law model | | | | | |
|---|---|---|---|---|---|---|
| | Basil seed gum | | | Balangu seed gum | | |
| | K (Pa.s$^n$) | n | R | K (Pa.s$^n$) | n | R |
| 20°C | 0.24$^{ab}$ | 0.67$^{c}$ | 0.997 | 0.22$^{ab}$ | 0.42$^{a}$ | 0.987 |
| 40°C | 0.25$^{a}$ | 0.69$^{bc}$ | 0.996 | 0.24$^{ab}$ | 0.36$^{b}$ | 0.992 |
| 60°C | 0.23$^{ab}$ | 0.72$^{ab}$ | 0.996 | 0.22$^{ab}$ | 0.33$^{bc}$ | 0.987 |
| 80°C | 0.21$^{b}$ | 0.75$^{a}$ | 0.996 | 0.21$^{b}$ | 0.30$^{c}$ | 0.96 |
| 100°C | 0.22$^{ab}$ | 0.75$^{a}$ | 0.996 | 0.25$^{a}$ | 0.23$^{d}$ | 0.93 |

* Means in a column followed by the different superscripts are significantly different at $p \leq 0.05$.

suitable time independent rheological model to characterize the flow behavior of gum solutions. Flow behaviour index (n) and consistency index (K) of 1% basil seed gum samples were 0.67 and 0.24 Pa.s$^n$, respectively, at 20°C. The pseudoplacticity increased with increasing temperature of basil seed gum solutions. In addition, it was found that the thermal treatments did not have destructive effect on seeds gums (heat stable) and their rheological properties improved after heat treatments. Apparent viscosity measurements of seeds gums before and after heat treatment indicated that basil seed gum was tolerant to temperatures commonly applied in food industry. Therefore, it can be employed as an appropriate choice to be used in the industrial processes involving high temperature.

## References

Dickinson, E. (2009). Hydrocolloids as emulsifiers and emulsion stabilizers. Food Hydrocolloids, 23, 1473-1482.

Downey, G. (2002). Quality changes in frozen and thawed, cooked puréed vegetables containing hydrocolloids, gums and dairy powders. International Journal of Food Science and Technology, 37 (8), 869–877.

Glicksman, M. (1982). Food hydrocolloids, Vol. 1e3, Florida: CRC Press.

Maciel, J. S., Silva, D.A., Paula, H. C. B. & de Paula, R. C. M. (2005). Chitosan/carboxymethyl cashew gum polyelectrolyte complex: synthesis and thermal stability. European Polymer Journal, 41, 2726–2733.

Manohar, B., Ramakrishna, P. & Udayasankar, K. (1991). Some physical properties of Tamarind (Tamarindus indica L.) juice concentrates. Journal of Food Engineering, 13, 241-258.

Marcotte, M., Taherian, A. R. & Ramaswamy, H. S. (2001a). Rheological properties of selected hydrocolloids as a function of concentration and temperature. Food Research International, 34, 695–704.

Marcotte, M., Taherian, A. R., Trigui, M. & Ramaswamy, H. S. (2001b). Evaluation of rheological properties of selected salt enriched food hydrocolloids. Journal of Food Engineering, 48, 157-167.

Moser, P., Cornélio, M. L. & Telis, V. R. N. (2013). Influence of the concentration of polyols on the rheological and spectral characteristics of guar gum. LWT - Food Science and Technology (In Press).

Naghibi, F., Mosaddegh, M., Mohammadi Motamed, M. & Ghorbani, A. (2005). Labiatae Family in folk Medicine in Iran: from Ethnobotany to Pharmacology. Iranian Journal of Pharmaceutical Research, 4(2), 63–79.

Sahin, H. & Ozdemir, F. (2004). Effect of some hydrocolloids on the rheological properties of different formulated ketchups. Food Hydrocolloids, 18, 1015–1022.

Salehi, F. & Kashaninejad, M. (2015). Effect of drying methods on rheological and textural properties, and color changes of wild sage seed gum. Journal of Food Science and Technology, 52(11), 7361-7368.

Salehi, F., Kashaninejad, M. & Behshad, V. (2014). Effect of sugars and salts on rheological properties of Balangu seed (Lallemantia royleana) gum. International Journal of Biological Macromolecules, 67, 16-21.

Salehi, F., Kashaninejad, M., Tadayyon, A. & Arabameri, F. (2015). Modeling of extraction process of crude polysaccharides from Basil seeds (Ocimum basilicum l.) as affected by process variables. Journal of Food Science and Technology. 52(8), 5220-5227.

Ramzi, M., Kashaninejad, M., Salehi, F., Sadeghi Mahoonak A. R. & Razavi, S. M. A. (2015). Modeling of rheological behavior of honey using Genetic Algorithm-Artificial Neural Network and Adaptive Neuro-Fuzzy Inference System. Food Bioscience, 9, 60-67.

Sánchez,V. E., Bartholomai, G. B. & Pilosof, A. M. R. (1995). Rheological properties of food gums as related to their water binding capacity and to soy protein interaction. LWT - Food Science and Technology, 28(4), 380–385.

Szczesniak, A. S. & Farkas, E. (1962). Objective characterization of the mouth feel of gum solutions. Journal of Food Science, 27, 381-385.

Vardhanabhuti, B. & Ikeda, S., (2006). Isolation and characterization of hydrocolloids from monoi (Cissampelos pareira) leaves. Food Hydrocolloids, 20, 885–891.

Yamazaki, E., Kurita, O. & Matsumura, Y. (2009). High viscosity of hydrocolloid from leaves of Corchorus olitorius L. Food Hydrocolloids, 23, 655-660.

Zameni, A., Kashaninejad, M., Aalami, M. & Salehi, F. (2015). Effect of thermal and freezing treatments on rheological, textural and color properties of Basil seed gum. Journal of Food Science and Technology, 52(9), 5914-5921.