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Effect of Fat Substitution on the Rheological and Textural Properties of Raw Chicken Meat Emulsion and Cooked Patties

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ABSTRACT

The present study was conducted to evaluate the rheological behaviour and textural properties of raw chicken meat emulsion and cooked patties respectively. Low fat chicken emulsions were prepared with the addition of pre-optimized levels of 1%lemon albedo, 2% mango peel powder, and 2% banana peel powder with the replacement of 50% vegetable oil in formulation The rheological behaviour of low fat emulsion and textural properties of these low fat emulsion based chicken patties were observed. The formulation of chicken meat emulsion was maintained by the addition of water with the replacement of fat. Dynamic oscillatory measurements revealed the weak gel formation of emulsions with addition of fat replacers, as storage modulus values (G′) were higher than the loss modulus values (G″). Chicken meat patties were prepared from these low fat chicken meat emulsions. Textual profile analysis of cooked patties showed a significant (P<0.05) effect on hardness, fracturability, cohesiveness, gumminess, and chewiness values. Therefore, it was concluded that replacement of fat with optimum level natural fat replacers (lemon albedo, mango peel powder and banana peel powder) resulted in predominant visco-elastic behaviour of emulsions which in turn had a significant effect on textural properties of the emulsion. Hence, the visco-elastic behaviour of emulsion and the effect of textural properties might improve the acceptability of cooked low fat chicken patties.

Key words: Fat substitution, Chicken meat emulsion, Lemon albedo powder, Mango peel powder, Banana peel powder, Rheological characteristics, Textural Properties

INTRODUCTION

Muscle proteins are the major structural and functional components in the processed meat system. Emulsion-based meat products play an important role in the modern meat industry, though a meat batter is prepared traditionally for a long back in history. Functional properties of meat protein in emulsion based products can be broadly emphasized on the basis of protein-water interactions, protein-fat interactions, and protein-protein interactions (Smith *et al.* 2001). Meat batter is a heterogeneous mixture of protein-coated fat globules (oil droplets) dispersed in a myofibrillar protein gel matrix (Dickinson, 2012), produced through comminution process. Comminuted emulsion based meat products like chicken patties are mainly affected by the raw material quality and composition (Turhan *et al.* 2005). Fat content, fat globules size, and amount of solubilized protein to cover the fat surface area (interfacial adsorption) are important factors (Hoogenkamp 2011) for maintaining good emulsion stability. Fat is an essential component as it improves the juiciness, tenderness, and overall palatability of emulsion-type products. Acceptable quality patty preparation necessitates 20-30 g of fat content per 100 of the emulsion based product, as fat reduction in emulsion based meat products to lower than 20 g per 100 g usually exhibit rubbery texture (Angor and Al-Abdullah 2010). However, product with high fat content may exert harmful impacts on human health such as obesity and high blood cholesterol levels (Ozvural and Vural 2008). Present day consumers are highly conscious for nutrients, especially meat fats and salt, they consume (Pietrasik and Janz 2010) and demand functional meat products with the addition of health beneficial ingredients without affecting sensory quality. Substitution of fat with plant based byproducts may improve the acceptability of processed meat products.

Fruit and vegetable by-products are a potential source of non-digestible components (fibre) and bioactive compounds (phenolics, carotenoids, and flavonoids), which contribute synergistically to human health contributing to constructive, nutritional, and technological activities. From a nutritional and environmental point of view, it is better to use fruit by-products to develop health-oriented food products to convene consumers demand (Yıldız-Turp and Serdaroglu 2010). Lemon is an important medicinal plant of the family *Rutaceae.* Lemon albedo is a white, spongy, and cellulosic tissue, which is the principal component of the citrus peel and could be considered a potential source of fiber, which improves the functional properties of meat products (Fernandez-Gines *et al.* 2004). Banana (*Musa sapientum*) is a very popular fruit having high nutrients and low prices. It is cultivated universally and consumed generally as fresh fruit. The peel or skin of a banana is usually considered a waste product. Banana (*Musa sp., Musaceae)* peel contains around 43–49 g of total dietary fibre (DF), 1 g of inulin, 6 g of fructooligosaccharide and 10–20 g of pectin per 100 g of dry matter, in addition to significant amounts of α-linolenic acid (ALA), essential amino acids and micronutrients such as Mg, K, P and Ca (Mohapatra et al. 2010). The mango is indigenous to the Indian subcontinent and Southeast Asia (Fowomola 2010). The peel represents approximately 20% of the fruit and is an excellent source of nutrients and nutraceutical compounds that could be used to generate economic profit in the food industry, thereby mitigating and solving environmental problems (Thomas *et al.* 2013). Processing steps such as speed of mixing, chopping time, the final temperature of the emulsion (Carpenter and Saffle 1964) as well as protein and fat levels had significant effects on the stability of meat emulsions (Youssef and Barbut 2009). Recently Indian emulsion based meat product market is gaining importance and producers are in crucial need of scientific processes for the production of emulsion meat products with better yield, good sensory qualities, and nutrition. Considering the demand of consumers, industry, market need, and health promoting properties of fruit byproducts, the present study was aimed to evaluate the behaviour and textural properties of low fat chicken meat emulsion using natural ingredients to give an assurance regarding the quality of the cooked product in terms of textural properties (Herrero *et al.* 2008).

MATERIALS AND METHODS

The experiments were conducted in the department of Livestock Products Technology, DUVASU, Mathura, and Division of Goat Products Technology, CIRG, Makhdoom. The raw chicken meat was procured from an authorized retail meat shop located in Mathura city. The required quantity was purchased within 1-2 h of slaughter, packed in pre-sterilized low-density polyethylene (LDPE) bags, and brought to the laboratory within 20 min. The meat was deboned, and trimmed-off separable fat and connective tissue. The samples were kept for conditioning in a refrigerator at 4±1°C for 6–8 h and then frozen at -18°C till further use. Food-grade refined vegetable oil (FortuneVR), sodium tripolyphosphate (Hi Media Laboratories (P) Ltd, Mumbai), salt, condiments, refined wheat flour, and mangoes were purchased from the local market of Mathura. For the preparation of the spice mix, ingredients were procured from the local market and weighed as per formulation, dried at 45±2°C for 2 h followed by grinding and sieving through the mesh. The prepared spice mix was stored in pre-sterilized LDPE bags and used during the preparation of products as per the requirement composition (Table 1).

Mango peels, lemon albedo, and banana peels were cut into small pieces and dried in a hot air oven at 50±2°C for 48 h till constant moisture content (up to 5%) was obtained. Dried peels were ground separately into fine powder form in the Inalsa Maxie food processor, tightly sealed in low-density polyethylene bags, and stored at refrigeration temperature till further use (Fernández-Ginés *et al.* 2003). All chemicals used in the study were of analytical grade and procured from standard firms like Hi Media Laboratories (P) Ltd, Mumbai.

Table 1: Composition of spice mix

Serial No.	Spices	Percentage (%)
	Black cardamom (Badi elaichi)	5
	Cinnamon (Dalchini)	20
	Turmeric (Haldi)	10
	Clove (Loang)	5
	Red chilli	10
	Coriander (Dhania)	20
	Cumin (zeera)	10
	Black pepper (Kalimirch)	10
	Aniseed (Soanf)	10
	Total	100

Emulsion and product preparation

The chicken meat emulsion and patties were prepared according to the method prescribed by Nayak (2015) with slight modifications (Table 2).

Table 2: Formulation for raw chicken meat emulsion/cooked patties

S. No.	Ingredient (%)	C	LA1	MP2	BP2
1	Chicken	74.2	74.2	74.2	74.2
2	Refined vegetable oil	8	8	8	8
3	Fat replacer	0	4	4	4
4	Water	0	4	4	4
5	Ice flakes	8	8	8	8
6	Salt	1.5	1.5	1.5	1.5
7	Dry spices mix	2.0	2.0	2.0	2.0
8	Condiments	3.0	3.0	3.0	3.0
9	Refined wheat flour	3.0	3.0	3.0	3.0
10	STPP	0.3	0.3	0.3	0.3
	Total	**100**	**100**	**100**	**100**

Frozen deboned meat was thawed at refrigeration temperature overnight. The thawed lean meat was cut into smaller chunks and minced in a meat mincer (Sirman mincer, MOD-TC 32 R10U.P. INOX, Marsango, Italy) with a 6mm plate followed by a 4mm plate. The common salt, vegetable oil, refined wheat flour (maida), sodium tripolyphosphate, spice mixture, and condiment mix were weighed accurately as per the formulation. The minced meat was blended with salt, and sodium tripolyphosphate for 1.5 min. Thereafter ice flakes were added and blending continued for 1 min. This was followed by the addition of refined vegetable oil and blended for another 1-2 min. Then, the spice mixture, condiments, and other ingredients were added and again mixed for 1.5-2 min to get the desired emulsion. Low fat chicken meat emulsion was prepared with the replacement of 50% vegetable fat with lemon albedo (1%), mango peel powder (2%), and banana peel powder (2%) separately. in three different treatments. The formulation was maintained with the addition of chilled water accordingly. Meat emulsion was prepared in Sirman Bowl Chopper (MOD C 15 2.8G 4.0 HP, Marsango, Italy). Adequate care was taken to maintain a temperature below 18°C by preparing the emulsion in cool hours of the morning, by adding chilled meat, other ingredients and by addition of crushed ice. Chicken patties were moulded using about 50 g of emulsion on a steel plate with a circular ring (55mm diameter and 20mm height). The height and diameter of the patty were determined by Vernier callipers. Patties were cooked in a pre-heated convection oven at 160°C for 15min after which they were turned upside down and cooked for another 5 min for adequate doneness and to improve the appearance and colour. The core temperature was measured by using a probe thermometer (Labware Scientific, Inc, USA) to ensure proper cooking of patties at 72°C. Raw chicken emulsions were cooled to room temperature at 25°C and then packed in pre-sterilized LDPE pouches. The formulation of chicken meat emulsion /chicken patties is given in table 2 and the treatments in the present study are abbreviated as: C (control): chicken meat emulsion/cooked patties with 0% fat replacer LA1: Low fat chicken meat emulsion/cooked patties with 1% lemon albedo replacing 50% vegetable fat; MP2: Low fat chicken meat emulsion/cooked patties with 1% mango peel powder replacing 50% vegetable fat and BP2: Low fat chicken meat emulsion/cooked patties with 1% banana peel powder replacing 50% vegetable fat respectively.

Rheological parameters

Rheological characterization of meat emulsion was assessed by using Rheometer (MCR 72, Anton Paar GmbH, Austria) equipped with a parallel plate system DPP75-SN000000 (25 mm diameter) according to the method given by Graça et al. (2016) with modifications. The rotational mode was used to investigate time-related behaviour of emulsion. Meat emulsion was placed onto the centre of the base plate. The upper plate was moved into position, that is, the distance between the two plates (gap) was set to 1 mm and the excess emulsion was trimmed from the plate edges. In order to avoid evaporation during tests, all the samples were covered with a thin film of silicon oil. Heating curves were applied to all samples to study the structural changes resulting from the variation of temperature at the rheometer plate, heating from 20°C to 90°C, at 1°C/min heating rate. During the heating profile mentioned, carried out at 1 Hz of frequency and constant stress. The storage modulus

(G′) and loss modulus (G″) is a measure of elastic energy stored in the samples which were recorded.

The viscoelastic characteristics of the chicken emulsion were continuously monitored using a dynamic rheometer (MCR72, Anton Paar Ltd., Austria) equipped with a parallel plate system DPP25-SN000000 (25 mm diameter) under an increase in frequency (1rad/ s). Twenty five millimetre diameter parallel stainless steel plate geometry with a 1 mm gap was used. The samples of batters were gently placed onto the plate and allowed to equilibrate for 5 min at 20°C. Frequency sweeps from 0.1 to 100 rad/ s were performed on the meat batters at 20°C and a fixed strain of 100 Pa. The storage modulus (G′) and loss modulus (G″) were recorded as a function of frequency. All measurements were done in triplicate.

Texture profile analysis

The texture profile analysis of chicken patties was done with the help of instrumental texture profile analyser (TA XT Plus Texture analyser) at Goat Products Technology, CIRG, Makdhoom as per Bourne (1978). The following parameters were determined *viz.* Hardness (N/cm2), Springiness (cm/mm, Cohesiveness (Ratio), Gumminess (N/cm2 or g/mm2) and Chewiness (N/cm or g/mm). The conditions (test descriptions) set for analyses were as follows:

Pre test speed	:	2mm/sec
Test speed	:	2 mm/sec
Post test speed	:	5 mm/sec
Target mode strain	:	60%
Time	:	5 sec
Trigger type	:	Auto (F)
Trigger force	:	0.04903 N
Break mode	:	Off
Tare mode	:	Auto
Probe	:	P75 compression plating

Statistical analysis

The data obtained in the study for texture profile analysis was statistically analysed on “SPSS-20.0” software package for one-way ANOVA as per standard methods of Snedecor and Cochran (1994). Duplicate samples were drawn for each parameter and the experiment was replicated thrice (n=6). Data were subjected to one-way analysis of variance, homogeneity test, and means were compared by using Duncan’s (1995) multiple range tests to find the effects between samples.

RESULT AND DISCUSSION

Rheology of chicken meat emulsion

The temperature sweep of chicken emulsion incorporated with the optimum level of different fat replacers is presented in fig 1. Storage modulus values (G′) were higher than loss modulus values (G″) on the addition of different fat replacers during the applied temperature range (20 to 90^{o}C) as well as frequency.

The phase angle data was especially variable in the high-temperature zones, a rapid increase in G′ and G′ modulus was observed as the temperature rose above 50^{o}C for emulsion treated with different fat replacer and at 60^{o}C for control emulsion. Highest G′ modulus was observed in BP2>LA1>MP2>C, however and G″ modulus was observed in LA1>MP2>BP2>C. From the study, it is clear that the control sample had the least storage as well as loss modulus, as it has a higher amount of fat with no natural fat. In contrast, the emulsions treated with different fat replacers showed higher elastic as well as viscous behaviour than the control. This might be due to the replacement of 50% fat with lemon albedo, mango peel, and banana peel powder. Among treatment emulsion treated with mango peel powder had lower elastic behaviour which might be due to the presence of pectin in mango peel powder and less fat content in the formulation which give the most compact character. It has been suggested that if the storage modulus is larger, it reflects a strong particle-particle interaction or a stabilized network structure (Acevedo et al. 2014). The findings are in close agreement with Diofanor et al. (2018) for fat-substituted meat emulsions. Similar results were reported by Florez et al. (2007) showing a stronger gel of caseinate-treated meat paste, confirming that the starch contributed in certain degree of emulsion stability.

The frequency sweep of chicken emulsion incorporated with the optimum level of different fat replacers is presented fig 2.

In frequency sweep, G′ modulus were decreased with an increase in the angular frequency from 0.91-0.231, 0.91-0.148, 0.91-0.231 and 0.91-0.231 for control, LA1, MP2, and BP2 respectively thereafter it increased significantly. However, G′ modulus decreased as the angular frequency increased from 0.91-1.11 for control, 0.91- 0.567 for LA1, 0.91-0.709 for MP2, and 0.91-0.887 for BP2, thereafter values for both the modulus were increased significantly. No cross-point was observed at all ranges of frequency in meat emulsions prepared with the incorporation of different fat replacers. The G′ was higher than the G′. Higher

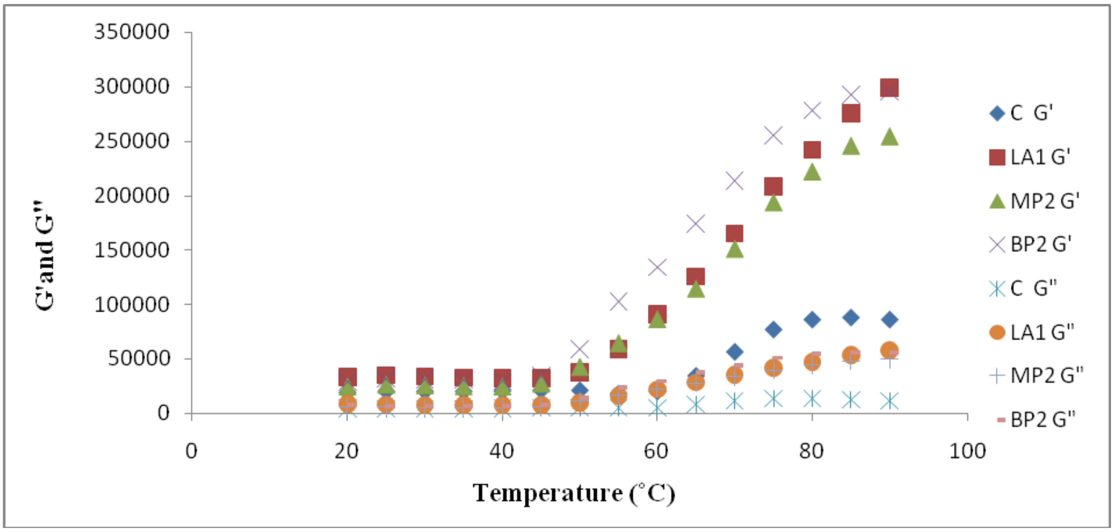

Fig. 1. Temperature sweep of chicken emulsion incorporated with optimum level of different fat replacers

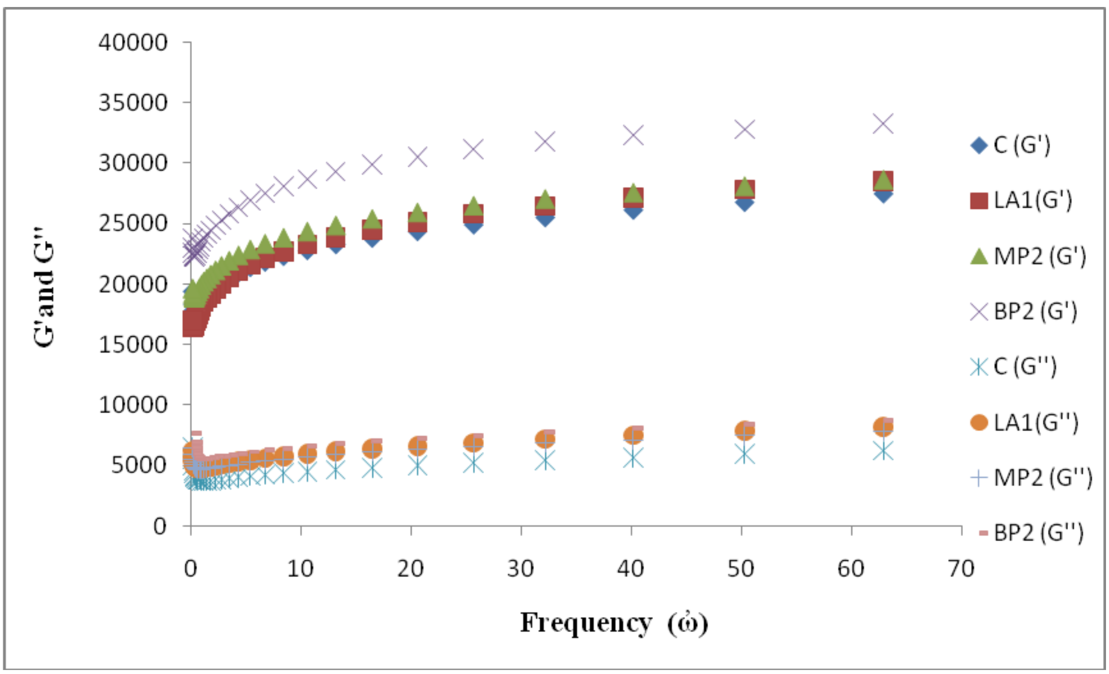

Fig. 2. Frequency sweep of chicken emulsion incorporated with optimum level of different fat replacers

G′ was observed in LA1>BP2>MP2>C, while G′ modulus in BP2> LA1>MP2>C. Similarly, Genccelap et al. (2015) reported that the values of the storage modulus of studied meat emulsions were always higher than the loss modulus at each angular frequency (ω), which shows that meat emulsions have an elastic rather than viscous characteristic. Therefore, emulsions can be described as weak gel or have a gel-like behaviour. Protein level and fat type had significant effects on the stability of meat emulsions (Youssef and Barbut 2009), interfacial protein film thickness and the integrity and density of the surrounding emulsion matrix, and its ability to retain that integrity during thermal processing are major factors for emulsion stability (Jones and Mandigo 1982).

The result showed that both storage and loss modulus increased with an increase in frequency. It is clear from the study that the behaviour of emulsion depends on frequency, possible reason behind this might be the replacement of fat with fruit by-products which improves the water binding and the different levels of water added to maintain the formulation. Genccelap et al. (2015)

claimed that the addition of potato starch increased viscoelastic properties i.e. both the elastic and viscous modulus values of G' and G". Marcheti et al. (2014) also reported that the storage modulus G' showed a predominantly elastic behaviour, indicating weak gel characteristic (Ross-Murphy 1984). In addition, the elastic modulus G' had higher values than the leakage or viscous modulus in the tested frequency range.

Texture profile analysis

The textural properties of functional chicken patties incorporated with mango peel powder are presented in Table 3.

MP2 had significantly (P<0.05) higher hardness, gumminess, and chewiness values than C and the other two treatments, however, there was no significant difference between LA1 and BP2. Fracturability values of MP2 and BP2 were significantly (P<0.05) higher than C, however values of LA1 were comparable to C, MP2 and BP2. Springiness, cohesiveness, and resilience values of C and MP2 were significantly (P<0.05) higher than LA1 and BP2. Higher textural values in MP2 than control and other treatments might be due to the presence of the biological compound pectin responsible for textural changes in the product with the addition of mango peel powder. Chappalwar et al. (2020) also observed significantly (P<0.05) higher textural parameters for mango peel powder treated patties. Goswami et al. (2017) also observed significantly (P<0.05) higher hardness and shear force values in mango peel powder incorporated carabeef cookies. The results of the present study are in agreement with Min et al. (2010), who reported higher textural values in functional meat cookies prepared with 10-30 per cent apple derived pectin-enriched material. The lower values of LA1 and BP2 than control might be due to the dilution effect of lemon albedo and banana peel on meat protein system, as water and fat binding property provides soft texture to the product. Eda et al. (2015) also observed tender and smooth hamburgers incorporated with lemon fibre due to lower gumminess, springiness and chewiness values. Fu et al. (2015) also reported a decrease in the cohesiveness, springiness and chewiness of manotu (steamed bread) with increased level of lemon fibre. Yalinkiliç et al. (2016) observed a decrease in textural parameters with reduction of fat in sucuk, a dry fermented sausage. Textural properties of meat products are affected by water holding capacity, emulsion stability, gelling ability, and addition of non meat ingredients (Choi et al. 2008). Present findings for LA1 and BP1 are in close agreement with Verma et al. (2015) who observed lower hardness and higher cohesiveness values for sweet potato powder treated low fat pork patties than the control.

CONCLUSION

The effect of different fat replacers on the rheological parameters of meat emulsion was evaluated. The measured G' and G" indicated strain and temperature functions during frequency scanning and temperature scanning. A thermal study revealed that the control emulsions had the highest visco-elastic behaviour. Frequency sweep curves indicated that the meat emulsions in the model system behaved like a weak gel with the addition of fat replacers. The addition of different fat replacers in the meat emulsion formulation improved the emulsifying ability of meat proteins and resulted in a more uniform emulsion matrix and modelling of rheological parameters on the addition of different fat replacers. Among different fat replacers, mango peel powder had improved textural properties mimicked with control products. Thus, it was concluded that well acceptable low-fat meat emulsions prepared with the addition of mango peel powder could be used during the manufacturing of emulsion based chicken patties.

Table 3: Texture profile analysis of functional chicken patties incorporated with optimum level of different fat replacers (Mean ± S.E.)

Parameter	C	LA1	MP2	BP2	Treatment mean
Hardness (N/cm^2)	42.45^{b}±2.94	31.47^{c}±1.33	52.80^{a}±2.76	31.22^{c}±2.00	39.49±2.15
Fracturability (Ns)	0.09^{b} ±0.00	0.11^{ab}±0.00	0.12^{a}±0.00	0.13^{a}±0.00	0.11±0.00
Springiness (cm)	0.83^{a}±0.00	0.53^{b}±0.01	0.84^{a}±0.01	0.40^{c}±0.02	0.65±0.04
Cohesiveness (ratio)	0.40^{a}±0.01	0.20^{b}±0.01	0.41^{a}±0.01	0.18^{c}±0.00	0.29±0.02
Gumminess(N/cm^2)	16.61^{b}±1.45	6.46^{c}±0.45	21.67^{a}±1.83	6.48^{c}±0.63	12.80±1.48
Chewiness	14.29^{b}±1.20	2.63^{c}±0.30	18.41^{a}±1.49	3.47^{c}±0.34	9.70±1.49
Resilience	0.11^{a} ±0.00	0.04^{b}±0.00	0.11^{a} ±0.00	0.05^{b}±0.00	0.08±0.00

Overall means bearing different superscripts in a row (a, b, c, d…) differ significantly (P<0.05)

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