The effects of powdered suji leaves (Dracaena angustifolia (medik.) roxb.) on the pasting properties of wheat flour and characteristics of steamed bun

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Abstract. Water-extract of fresh suji leaves has been traditionally used as a green food colorant in Indonesia. Innovations of whole suji leaves into powder form are expected to fulfill the zero-waste concept and be a more applicable natural food colorant than using fresh leaves. This study aims to evaluate the changes in pasting properties of wheat flour and characteristics of steamed buns as affected by adding powdered suji leaves (PSL). The study is done following Randomized Block Design with PSL concentration (0-5%) as the factor. The results show that the increase of PSL concentrations significantly (α = 0.05) reduces pasting properties of wheat flour except pasting temperature, increases the green color, and reduces the moisture content of the dough, as well as reduces specific volume and texture profile of steamed buns. Considering the role of PSL as a natural coloring food additive, it is expected to add the least concentration to create green color without creating negative effects for the other steamed bun qualities. This study shows that the PSL at a concentration of 1% is sufficient to produce a green color (L*, a*, b* crust 70.45, 2.16, 25.8) steamed buns with volume (91.00 cm³), specific volume (3.15 g/cm³), moisture content (crust 33.01%, crumb 35.27%) and texture profile (cohesiveness 0.67, springiness 0.92, chewiness 246.46 g and resilience 0.32), and these qualities are comparable to the steamed buns without PSL.

1. Introduction
Pandan suji or suji plant belongs to the Dracaena genus that is easily found in the tropical area of Indonesia, Malaysia, Vietnam, and New Guinea [1]. The suji plant is characterized by the dark-green leaves in the shape of an elongated ribbon with a size approximately 17 x 2.5 cm arranged on a trunk with a distance in between of 0.5 cm. Fresh suji leaves contain 73.25% moisture, 3773.9 ppm of total chlorophyll consisting of 2524.6 ppm of chlorophyll a and 12503 ppm of chlorophyll b [2].

Indonesians traditionally utilize suji leaves as green colorants for many food products. The green color of suji leaves is obtained from the chlorophyll compounds located in the chloroplast, therefore it requires breaking the leaves’ cell to extract the chlorophyll. This method is time consuming and requires a short shelf-life of fresh suji leaves and produces waste after the extraction process is completed. These conditions are less comfortable for modern people who demand something practical.
Therefore, the transformation of fresh suji leaves into powdered suji leaves (PSL) is expected to overcome these problems, as well as to fulfill the zero-waste concept.

Chlorophyll is sensitive and easily degraded by heat, light, oxygen, acids, and enzymes producing the structural chlorophyll change. Chlorophyll can be degraded to be pheophorbide a (PPBa), the chlorophyll which loses the phytol chain as well as a magnesium atom which is centrally located coordinated with the nitrogen of the four pyrroles [3]. This damage changes the chlorophyll color from green to a light green or brownish green [4]. Therefore, to minimize chlorophyll damage, suji leaves are dried in a not too high temperature, 40°C, cabinet dryer before suji leaves are powdered and sifted 100 mesh. The PSL then can be applied as a food colorant such as in the steamed buns making.

Steamed buns or steamed bread is a fermented dough made from wheat flour and steamed. The steaming process produces a thin, white skin, with crumb ranging from firm and dense to soft and open depending on region and type of steamed buns [5]. Steamed buns have been believed to have originated from China under the name Mantou; and later, it also became a well-known snack in Indonesia. Based on the data of Food Consumption Statistics by the Ministry of Agriculture [6], steamed cake consumption from 2011 to 2015 has increased by 17.78%, and in 2015 consumption of processed steamed cake products, including steamed buns in Indonesia, reached up to 64.918 units per capita per year.

The steamed buns are white, but the commercial steamed bun’s colors are currently more varied, including green. This study evaluates the use of PSL as a green dye for steamed buns. Apart from containing chlorophyll which can give a green color, the PSL also contains other components such as fibers, minerals, and many phytochemical compounds. Phytochemical compounds in suji leaves include alkaloids, flavonoids, tannins, terpenoids, saponins, polyphenols, monoterpenoids, sesquiterpenoids, and glycosides [7]. The presence of fibers, minerals and phytochemical compounds may change the pasting properties of wheat flour, characteristics of dough and steamed buns. This research aims to study the effect of the concentrations of the addition of PSL on the pasting properties of wheat flour, the physical properties of the dough and steamed buns.

2. Materials and Methods
The main material used in this study is the fresh suji leaves obtained from the Technical Implementation Unit of The East Java Province Health Office (Materia Medica Batu). The supporting ingredients for making steamed buns are the high protein wheat flour (Cakra kembar), sugar (Gulaku), margarine (Blueband), instant yeast (Fermipan), salt (Kapal), powdered milk (Dancow) and mineral water.

PSL is prepared by the sequence of processes; sortation of the fresh suji leaves, washing with tap water, reducing the size using a chopper, drying in a 40°C cabinet dryer for 6 h, reducing the dried suji leaves size with dry blender for 5 min, further grinding the crushed-dried suji leaves with a ball mill at a speed of 115-118 rpm during 30 min. The finely ground dried suji leaves (PSL) then are obtained after sieving the powder through a 100-mesh screen.

Steamed buns are prepared using the formulation containing a total flour of 100 g (wheat flour: PSL ratios are 100:0, 99:1, 98:2; 97:3, 96:4, and 95:5), powdered milk 5g, sugar 20g, salt (NaCl) 1g, margarine 14 g, instant yeast 2.2 g and water 55 ml. All the ingredients are mixed using a standing mixer (Kitchen aid) until the dough is nicely formed. Then, the dough is rounded, rested for 30 minutes, deflated and rounded with a weight of 50 grams each, proofed at 29 ± 1°C for 60 min, and steamed for 20 minutes. Steamed buns are cooled at room temperature for 5 minutes for further analysis.

Analyses are done for PSL, wheat flour containing 0-5% PSL, and steamed buns. PSL is analyzed for dietary fiber (the enzymatic method) and minerals content (XRF). Wheat flour containing 0-5% PSL is analyzed for pasting properties (RVA 4 Stand Alone, Newport Scientific, Australia). Steamed buns are analyzed for color Lab, weight, height and diameter ratio, volume (AACCi standard method 10-15.1 seed displacement), moisture content of crumb and crust (gravimetric method) [8], and profile texture (Texture Analyzer Brookfield Engineering Labs Inc., USA).
The study is conducted following a Randomized Block Design one factor, levels of PSL substituted to wheat flour (0, 1, 2, 3, 4, and 5%). The study is replicated 4 (four) times. The experimental data is statistically analyzed by analysis of variance (ANOVA) using Minitab 17 software. Tukey HSD is used to separate means at p < 0.05.

3. Results and Discussion

3.1. Dietary fibers and minerals contents of PSL

The dietary fibers and minerals contents of PSL were analyzed with and without sieving, passing through a 100-mesh screen. The results can be seen in Table 1.

| Compounds        | Without sieving | Passed through 100 mesh | Compounds        | Without sieving | Passed through 100 mesh |
|------------------|-----------------|-------------------------|------------------|-----------------|-------------------------|
| Soluble fiber    | 7.51            | 7.52                    | Sr_LA            | 0.004           | 0.007                   |
| Insoluble fiber  | 34.12           | 34.30                   | Ba_LA            | 0.002           | 0.003                   |
| SiO₂             | 0.21            | 0.68                    | Cr_LA            | 0.002           | 0.002                   |
| Al₂O₃            | 0.04            | 0.12                    | Zr_LA            | Nd              | nd                      |
| Fe₂O₃            | Nd              | 0.1                     | Co_LA            | Nd              | nd                      |
| CaO              | 2.07            | 3.14                    | Cu               | 0.002           | 0.003                   |
| MgO              | 0.47            | 0.57                    | Ni               | 0.008           | 0.009                   |
| MnO              | 0.004           | 0.006                   | Pb_LA            | Nd              | nd                      |
| TiO₂             | 0.024           | 0.031                   | Zn               | 0.004           | 0.01                    |
| V₂O₅             | 0.018           | 0.017                   | Sn_LA            | Nd              | nd                      |
| SO₃              | 0.016           | 0.233                   | Cl               | 0.838           | 0.977                   |
| P₂O₅             | 0.533           | 0.536                   | LOI1000          | 94.3            | 91.7                    |
| K₂O              | 2.42            | 2.74                    | Total C          | 43.2            | 41.2                    |
| Na₂O             | 0.12            | 0.06                    | C organic        | 25.5            | 24.2                    |

Note: nd = the content is under 0.001 %

The total fiber content of PSL is quite high (42%). Fiber is a nutritional compound giving benefits to human health by helping the digestive system. Indonesians, in general, need 30g fiber per 2150 kcal of daily energy needs [9]. Therefore, PSL can be a coloring agent as well as a source of fiber. The addition of fiber source ingredients into the food formulation may affect several technological qualities such as mixing time, acceptance of color, appearance, and texture. However, the addition of fiber source does not influence on proofing time, color acceptance and appearance of crust (skin), taste, and aroma of bread [10].

PSL contains minerals such as calcium, potassium, and others, and no toxic heavy metals such as Pb, Co, and Sn are found (Table 1). The five highest minerals content in PSL measured with XRF is Ca and K with each in the range of 2-3%, Cl, P, and Mg in the range of 0.5-1%. These minerals can provide technological and nutritional functions when applied to making steamed buns. Calcium ions increase water absorption, dough stability, and gelatinization temperature [11]. Adding the calcium may help prevent calcium deficiency, while the calcium does not decrease the bread quality [12].

3.2. Pasting properties of wheat flour containing 0–5% PSL

Pasting properties greatly affect the quality and aesthetics of starch-based food products. Incorporation of PSL at a concentration of 1% does not change the pasting properties of wheat flour. However, PSL significantly changes the pasting properties at the higher levels, except for the pasting temperature of wheat flour (Figure 1 and Table 2).

The peak viscosity of wheat flour begins to decrease by 3% addition of PSL. Peak viscosity is influenced by starch, also the ratio of amylose and amylopectin [14]. The presence of components such as protein, fiber, fat, and ash can inhibit starch granules hydration, therefore reducing the ability of the starch to swell. The reduced ability of starch swelling which initiates the gelatinization process...
will reduce the peak viscosity value [15]. The ingredients derived from vegetables can reduce the peak viscosity value of flour [16]. The decrease of (wheat flour) breakdown and peak time significantly occurred in the addition of PSL at 4%. The breakdown rate of flour depends on the properties of the ingredients, the temperature, and the degree of mixing of the flour. The breakdown is an indication of the stability level of the gelling and is highly dependent on the nature of a product [18]. Peak time has a positive correlation with the distribution and chain length of amylose contained in the flour. The powders derived from plants can significantly reduce breakdown and peak time [16]. The addition of 2% PSL decreased the final viscosity, setback, and trough viscosity of wheat flour. Final viscosity is the ability of the flour to form viscous paste after cooking and cooling. The low value of the final viscosity indicates the low ability of the flour to form a thick paste. The setback correlates with the texture of the product and is an index of the tendency of the heated starch to harden under cooling conditions due to retrogradation [19]. The addition of PSL will increase the fiber that can bind water in large quantities so that the starch retrogradation process can be reduced. A lower setback indicates a lower tendency for starch granules to retrograde during cooling and during storage [20]. Trough viscosity is the minimum viscosity in the constant temperature phase of the pasting characteristics. A decrease in trough viscosity reflects a decrease in the elasticity of the dough. Increasing fibers can decrease trough viscosity [16].

The pasting temperature of wheat flour is not significantly affected by adding PSL at the level of 0-5%. Pasting temperature is the temperature at which the viscosity of starch begins to increase, and it is the minimum temperature needed to cook flour [20]. The increase in pasting temperature will only occur when the addition of powder from plants is at concentrations ranging from 5 to 25% [16].

Figure 1. The RVA pasting properties of wheat flour added with PSL at 0-5%.

3.3. Characteristics of steamed buns containing PSL
The characteristics of steamed buns such as weight, W/H ratio, volume and specific volume are not significantly affected by PSL at 1%. However, increasing levels of PSL decrease the heights and volume and increases the diameters of steamed buns. Added PSL means increasing fiber content while decreasing gluten and starch content of the wheat flour-based dough system. Fiber competes with protein gluten to absorb water. Fiber also disturbs gluten hydration causing poor viscoelastic properties of dough [22], and gluten network development. Fiber reduces gluten capacity to retain gas (CO₂) produced by yeast both during fermentation and the early stage of steaming. The gluten network may collapse and some gases escape during steaming, therefore, steamed buns expand sideways more than expands upwards. The specific volume of steamed buns containing PSL of 0-5% still falls within the standard criteria. The specific volume (in mL/g) of Northern, Southern, and Guangdong steamed breads are 2-2.5, 3, and 2.6-3.4, respectively [5].
Incorporating PSL by 2% does not change the moisture content of the crust, while it is required as low as 5% to significantly change the moisture content of the crumb. The moisture content of the steamed buns’ crust is slightly lower than the moisture content of the crumb. The crust is the outermost part of steamed buns that are directly exposed to the heat during steaming. PSL contains high fibers (42%, Table 1), and fibers able to absorb and bind water so that the bound water does not easily evaporate during heating [25].

The L* value of the crust and crumb of the buns decreases with the increase of the levels of PSL. The brightness value of the steamed buns changes due to the chlorophyll content of PSL contributing to the dark green color. Fresh suji leaves contain chlorophyll of 3773.9 ppm [2]. The addition of PSL increases both the a* and b* value of the buns, due to the high temperature applied during steaming. The epimerization reaction occurs when chlorophyll is exposed to heat [26]. The heat causes the release of Mg+ ions which are replaced by hydrogen atoms to form pheophytin. Continued heating causes the formation of the green to brown color pyro pheophytins. The increase of the b* color may be due to pigment breakdown during steaming. The leaf chlorophylls are commonly associated with carotenoids. When chlorophylls are damaged by the heat of steam, the carotenoids, which are more heat-stable, will dominate the color [28].

| Level of PSL (%) | Weight (g)       | Width/Height (W/H) Ratio | Volume (ml) | Specific volume (g/cm³) |
|-----------------|------------------|--------------------------|-------------|------------------------|
| 0               | 28.91 ± 0.04a    | 1.89±0.19d               | 95.38 ± 2.72a | 3.30 ± 0.10a            |
| 1               | 28.87 ± 0.17a    | 2.02±0.06d               | 91.00 ± 2.42b | 3.15 ± 0.09b            |
| 2               | 28.84 ± 0.13a    | 2.14±0.06d               | 85.38 ± 3.94bc | 2.96 ± 0.14bc          |
| 3               | 28.64 ± 0.29a    | 2.33±0.10bc              | 79.38 ± 1.44d | 2.77 ± 0.07d            |
| 4               | 28.61 ± 0.34a    | 2.50±0.04bc              | 78.00 ± 3.03d | 2.73 ± 0.08d            |
| 5               | 28.53 ± 0.22a    | 2.79±0.25d               | 75.25 ± 2.02d | 2.64 0.06d              |

Note: Data are means of 4 replications (± standard deviation). The same symbol shows the insignificant different on Tukey’s HSD test α=0.05

### 3.4. Texture profile of steamed buns containing PSL

The hardness of the steamed buns increases with increasing levels of PSL added. The hardness of steamed buns could be related to the decrease of the volume and specific volume of buns with increasing concentration of PSL. The lower the volume, the lower the amount of gases in the buns. The texture is related to the amount of gases retained in the dough [29].

The addition of 0-5% PSL does not cause a significant effect on the cohesiveness of buns. Cohesiveness reflects the strength of the internal bonds that make up the crumb buns. Buns with a lower cohesiveness will produce a denser structure due to the decreased stability of the dough which has a more closed and brittle crumb structure [31].

The springiness of the steamed buns starts to significantly decrease at 5% PSL added. Springiness is the ability of a sample to return to its original form after the removal of deformation forces. The decrease in the springiness value relates to the weakening of the gluten structure which causes an increase in hardness and a decrease in the firmness of the buns. Steamed buns with a more porous crumb structure have a high springiness value. In contrast, buns with a low springiness have a denser structure, more closed crumbs, and brittle [31].

The Gumminess represents the force required to crush a semi-solid sample into a ready-to-swallow food form. The increase in gumminess value can be attributed to the higher hardness value of the buns with the increase in PSL. Increasing of buns’ gumminess can also be attributed to gelatinization. Hardness, gumminess, and chewiness are strongly influenced by the degree of starch gelatinization [32]. The buns’ dough is made with the addition of limited water, a maximum of 50% of the flour based [5], so that the gelatinization does not occur completely, and the fiber will reduce water that can be used by starch for the gelatinization.
Chewiness depicts the amount of energy required to chew a sample. The addition of PSL results in an increase in buns hardness and so the strength/energy needed to chew the sample. The addition of powder derived from purple sweet potato has been reported to cause a significant increase in the chewiness value with increasing powder added [33].

The resilience value of the buns is not influenced by the addition of PSL by a concentration of 5%, it only slightly increases in the addition of 4% PSL. Resilience is a value that determines how well a product can return its original height. Resilience, provides information about the recovery capacity after the sample is stressed. The lower the resilience, the lower the elasticity [34].

4. Conclusions
Suji leaves have been used as traditional green food colorants because of their chlorophyll. It also contains a decent source of dietary fibers and minerals. Total dietary fibers of PSL about 42%, consisting of 7.5% soluble fiber and 34% insoluble fiber. The main minerals content of PSL is calcium (2.07%), potassium (2.42%), Mg, P, and Cl each at the amount of 0.4-0.8%. Addition of PSL at the level by 1% does not significantly change the pasting properties of wheat flour. However, at a higher level of addition, it decreases almost all the pasting properties (the peak viscosity, trough viscosity, breakdown, final viscosity, setback and peak time) except the pasting temperature of wheat flour. Further, application of 1% PSL does not significantly affect dough and steamed buns characteristics. Therefore, it could be concluded that the 1% PSL can be used as a natural colorant for steamed buns without causing any detrimental effect on the quality.

References
[1] Wiart C 2013 Medicinal plants of China, Korea, and Japan. Bioresources for tomorrow's drugs and cosmetics. Deutsche Zeitschrift für Akupunktur, 56 2 56-57
[2] Prangdimurti E, Muchtadi D, Zakaria F R, Astawan M 2005 The effect of extraction solutions and incubation time on chlorophyll solubility and antioxidant capacity of suji (Pleomele angustifolia NE Brown) leaf extracts. Proceeding of the 9th Asean Food Conference 2005 9 8-10
[3] Eskin N A M, Hoehn E 2013 Fruits and Vegetables (Biochemistry of Foods vol 3) ed Eskin N A M, Shahidi F (San Diego: Academic Press) chapter 2 pp 49-126
[4] Comunian T A, Monterrey-Quintero E S, Thomazini M, Balieiro J C, Piccone P, Pittia P, Favaro-Trindade C S 2011 Assessment of production efficiency, physicochemical properties and storage stability of spray-dried chlorophyllide, a natural food colourant, using gum Arabic, maltodextrin and soy protein isolate-based carrier systems. Int. J. Food Sci. Tech. 46 6 1259-1265
[5] Huang S, Miskelly D 2019 Steamed bread – a review of manufacturing, flour quality requirements, and quality evaluation. Cereal Chem. 96 8–22
[6] Kementrian Pertanian Republik Indonesia 2015 Statistik konsumsi pangan 2015 (Food consumption statistics 2015) (Jakarta: Portal Epublikasi Pertanian, Kementrian Pertanian Republik Indonesia) [In Indonesian]
[7] Kinho J, Arini D I, Tabba S U, Kama H A, Kafiar Y E, Shabri S Y, Karundeng M C 2011 Tumbuhan obat tradisional di Sulawesi Utara jilid i balai penelitian kehutanan Manado (Traditional medicinal plants in North Sulawesi vol. i of Manado forestry research center) (Manado: Badan Penelitian dan Pengembangan Kehutanan dan Kementrian Kehutanan) [In Indonesian]
[8] AOAC 2011 Official methods of analysis of the AOAC 18th ed, rev 4 (Arlington: Association of official analytical chemist)
[9] BPOM RI 2016 Peraturan kepala BPOMRI nomor 9 tahun 2016 tentang acuan label gizi (Regulation of the head of BPOM RI number 9 of 2016 concerning nutrition labeling references) (Jakarta: Badan Pengawas Obat dan Makanan Republik Indonesia) [In Indonesian]
[10] Almeida E L, Chang Y K, Steel C J 2013 Dietary fibre sources in bread: influence on technological quality. *LWT – Food Science and Technology* **50** 2 545-553

[11] Codina G G, Zaharia D, Stroe S, Ropciuc S 2018 Influence of calcium ions addition from gluconate and lactate salts on refined wheat flour dough rheological properties *CyTA J. Food* **16** 1 884-891

[12] Bassett M N, Perez-Palacios T, Cipriano I, Cardoso P, Ferreira I, Samman N, Pinho O 2014 Development of bread with NaCl reduction and calcium fortification: study of its quality characteristics *J. Food Quality* **37** 2 107-116

[13] Li L, Zhang M, Bhandari B 2019 Influence of drying methods on some physicochemical, functional and pasting properties of Chinese yam flour *LWT* **111** 182-189

[14] Nimsung P, Thongngam M, Naivikul O 2007 Compositions, morphological and thermal properties of green banana flour and starch *Kasetsart J. (Nat. Sci.)* **41** 324-330

[15] Akoja S S, Coker O J 2018 Physicochemical, functional, pasting and sensory properties of wheat flour biscuit incorporated with Okra powder *Int. J. Food Sci. Nutr.* **3** 64-70

[16] Adegunwa M O, Adeniyi O D, Adebowale A A, Bakare H A 2015 Quality evaluation of kokoro produced from maize–pigeon pea flour blends *J. Culin. Sci. Technol.* **13** 200-213

[17] Maziya-Dixon B, Sanni L O, Adebowale A A, Onabanjo O O, Dixon A G O 2005 Effect of variety and drying methods on proximate composition and pasting properties of high quality cassava flour from yellow cassava roots. Proceedings of the African Crop Science Society Conference Entebbe Uganda 2005 8 635-641

[18] Sandhu K S, Singh N, Malhi N S 2007 Some properties of corn grains and their flours I: Physicochemical, functional and chapati-making properties of flours *Food Chem.* **101** 3 938-946

[19] Brennan C S, Cleary L J 2007 Utilisation Glucagel R in the [beta]-glucan enrichment of breads: A physicochemical and nutritional evaluation *Food Res. Int.* **40** 2 91–96

[20] Badifu G, Chima C, Ajayi Y, Ogori A, Ogori A 2006 Influence of mango mesocarp flour supplement to micronutrient, physical and organoleptic qualities of wheat-based bread *Niger. Food J.* **23** 1 59-68

[21] Schwartz S J, Cooperstone J L, Cichon M J, Von elbe J H, Monica giusti M 2017 *Colorants (Fennema’s food chemistry* vol 5) ed Damodaran S, Parkin K L (Boca Raton: CRC Press) chapter 10 pp 672-743

[22] Sivam A S, Sun-Waterhouse D, Quek S, Perera C O 2010 Properties of bread dough with added fiber polysaccharides and phenolic antioxidants: a review *J. Food Sci. 75* 8 R163–R174

[23] Gómez M, Moraleja A, Oliete B, Ruiz E, Caballero P A 2010 Effect of fibre size on the quality of fibre-enriched layer cakes *LWT - Food Science and Technology* **43** 1 33-38

[24] Dürenberger M B, Handschin S, Conde-Petit B, Escher F 2001 Visualization of food structure by confocal laser scanning microscopy (CLSM) *LWT - Food Science and Technology* **34** 1 11-17

[25] Brennan C, Kuri V 2006 Dietary fibre enrichment: effetc on food microstructure, nutrition and quality (Oxford: Blackwell Science)

[26] Santiago D M, Matsushita K, Tsuibo K, Yamada D, Murayama D, Kawakami S, Yamauchi H 2015 Texture and structure of bread supplemented with purple sweet potato powder and treated with enzymes *Food Sci. Technol. Res.* **21** 4 537-548

[27] Liu W, Brennan M, Serventu L, Brennan C 2017 Effect of wheat bran on dough rheology and final quality of Chinese steamed bread *Cereal Chem.* **94** 3
| Level of PSL (%) | Peak Viscosity (cP) | Trough Viscosity (cP) | Breakdown (cP) | Final Viscosity (cP) | Setback (cP) | Peak Time (min) | Pasting Temp (°C) |
|------------------|---------------------|-----------------------|----------------|---------------------|-------------|----------------|-----------------|
| 0                | 3120.00 ± 54.81a    | 2108.00 ± 32.08a      | 1012.00 ± 23.64b | 3540.33 ± 34.65a   | 1432.33 ± 35.81a | 6.09 ± 0.04a  | 68.03 ± 1.23a   |
| 1                | 3010.33 ± 58.05a    | 1968.00 ± 47.84ab     | 1042.33 ± 55.79a | 3351.33 ± 40.41ab  | 1383.33 ± 14.57ab | 5.96 ± 0.10ab  | 66.93 ± 0.03a   |
| 2                | 2843.67 ± 81.79a    | 1837.67 ± 41.36bc     | 1006.00 ± 40.63a | 3161.00 ± 60.01bc  | 1323.33 ± 20.13bc | 5.98 ± 0.08ab  | 68.08 ± 1.03a   |
| 3                | 2590.67 ± 92.14b    | 1628.33 ± 18.93cd     | 962.33 ± 94.52bc | 2895.00 ± 44.91cd  | 1266.67 ± 48.79c | 5.98 ± 0.10ab  | 67.91 ± 0.98a   |
| 4                | 2522.33 ± 77.11bc   | 1589.00 ± 80.47de     | 933.33 ± 17.62bc | 2837.00 ± 109.78de | 1248.00 ± 34.87cd | 5.87 ± 0.07b   | 70.78 ± 7.28a   |
| 5                | 2287.33 ± 173.79c   | 1439.33 ± 111.72c     | 848.00 ± 63.00c  | 2603.00 ± 152.25c  | 1163.67 ± 40.65d | 5.87 ± 0.00b   | 71.78 5.00a    |

Note: Data are means of 4 replications (± standard deviation). The same symbol shows the insignificant difference.

Table 4. Moisture content and color lab of steamed buns containing PSL

| Level of PSL (%) | Moisture content (%) | Crust color | Crumb color |
|-----------------|----------------------|-------------|-------------|
|                 |                      | Crust       | L*          | Crumb       | L*          |
|                 |                      | a*          | b*          | a*          | b*          |
| 0               | 34.81 ± 0.91a        | 76.50 ± 2.77a | 2.78 ± 0.39a | 10.47 ± 0.88c | 73.06 ± 0.69a | 2.86 ± 0.12b | 11.10 ± 0.17d |
| 1               | 33.01 ± 1.28ab       | 70.45 ± 1.20b | 2.16 ± 0.42b | 25.81 ± 0.30b | 67.37 ± 0.98b | 1.69 ± 0.16c | 20.75 ± 2.46c |
| 2               | 31.93 ± 0.49bc       | 65.10 ± 0.88b | 2.57 ± 0.28ab | 29.50 ± 0.81a | 61.06 ± 0.27c | 2.15 ± 0.12c | 27.25 ± 0.59ab |
| 3               | 31.05 ± 0.72bc       | 58.32 ± 1.87d | 3.11 ± 0.31ab | 29.64 ± 0.46a | 57.93 ± 1.46d | 2.05 ± 0.09c | 27.92 ± 0.92a |
| 4               | 30.27 ± 1.17c        | 53.29 ± 0.93e | 3.55 ± 0.36a  | 25.80 ± 1.16b | 51.62 ± 1.78e | 3.44 ± 0.49a | 25.53 ± 0.40ab |
| 5               | 29.75 ± 1.26c        | 49.43 ± 0.76f | 3.84 ± 0.10b  | 24.44 ± 0.61b | 48.37 ± 0.69f | 2.72 ± 0.09b | 24.82 ± 0.61b |

Note: Data are means of 4 replications (± standard deviation). The same symbol shows the insignificant different.

Table 5. Texture profile of steamed buns containing PSL.

| Level of PSL (%) | Hardness (g) | Cohesiveness | Springiness | Gumminess (g) | Chewiness (g) | Resilience |
|-----------------|--------------|--------------|-------------|---------------|---------------|------------|
|                 |              |              |             |               |               |            |
| 0               | 307.33 ± 25.58a | 0.71 ± 0.04ab | 0.93 ± 0.00a | 217.37 ± 21.91d | 201.61 ± 20.90d | 0.32 ± 0.01b |
| 1               | 401.24 ± 6.24d  | 0.67 ± 0.04b  | 0.92 ± 0.01a | 268.89 ± 13.69c | 246.46 ± 14.23cd | 0.32 ± 0.01b |
| 2               | 451.22 ± 5.21c  | 0.69 ± 0.03ab | 0.93 ± 0.01a | 310.50 ± 12.84a | 288.28 ± 14.78c | 0.33 ± 0.01b |
| 3               | 504.29 ± 22.99b | 0.73 ± 0.01ab | 0.92 ± 0.01a | 369.28 ± 25.74b | 341.14 ± 27.16b | 0.34 ± 0.01b |
| 4               | 531.65 ± 27.13b | 0.76 ± 0.01a  | 0.92 ± 0.03a | 401.82 ± 21.79b | 371.29 ± 20.40b | 0.41 ± 0.01a |
| 5               | 756.36 ± 9.82a  | 0.73 ± 0.05ab | 0.87 ± 0.02b | 548.68 ± 28.38a | 480.16 ± 33.19a | 0.34 ± 0.01b |

Note: Data are means of 4 replications (± standard deviation). The same symbol shows the insignificant different.