Pulses constitute an important source of dietary protein for large segments of the world’s population. Besides proteins, pulses provide energy, dietary fibre, minerals and vitamins required for human health. Among the pulses, kidney beans (*Phaseolus vulgaris* L.) and mash beans (*Phaseolus mungo* L.) have an important place with respect to production and consumption across the globe. Traditionally, pulses are consumed after cooking them in water until a desirable texture is obtained. However, the growing demand for functional ingredients necessitates the generation of information regarding properties of pulse-based products like flour, starch, and protein isolates. Present study entitled “Morphological, Thermal and Functional Properties of Native/Modified Proteins and Starch of Kidney Beans (*Phaseolus vulgaris* L.) and Mash beans (*Phaseolus mungo* L.)” was undertaken to characterise four cultivars of kidney beans and three cultivars of mash beans. Seeds of selected pulse cultivars were analysed for chemical composition, physical, cooking and textural properties. Pulse flours were evaluated for composition, physico-chemical properties (swelling and solubility index, syneresis, scanning electron microscopy), pasting properties, thermal properties, gel texture and functional properties. Starches were acetylated, studied for physico-chemical properties (swelling and solubility index, syneresis, freeze thaw stability, scanning electron microscopy), pasting properties, thermal properties and gel texture. Protein isolates were hydrolysed by papain and studied for thermal and functional properties. The pulse flour was also added to wheat flour to produce the unleavened flat bread.

Composition of kidney bean seeds revealed protein, fat, ash and carbohydrate content varied from 21.8 – 26.2%, 1.7 – 1.9%, 3.5 – 3.9% and 62.1 – 65.9%, respectively. Physical properties of kidney bean seeds at 10% moisture like length, breadth, thickness, sphericity, seed volume, surface area, bulk density and porosity were observed in the range of 11.45 – 16.45 mm, 6.65 – 7.80 mm, 4.70 – 6.13 mm, 52.13 – 63.08%, 113.83 – 223.96 mm³, 137.84 – 224.18 mm², 0.78 – 0.81 g/mL and 35.88 – 37.50%, respectively. Cooking properties of kidney bean seeds like hydration capacity, swelling capacity, cooking time and solid gruel loss varied from 0.12 – 0.42 g/seed, 0.09 – 0.28 mL/seed, 68.7 – 86.7 min and 14.08 – 15.8%, respectively. Mash bean cultivars had protein, fat, ash and carbohydrate content of 24.2 – 28.1%, 1.1 – 1.3%, 2.8 – 3.7% and 60.4 – 63.3%, respectively. Mash beans had significant (p ≤ 0.05) differences in length (4.66 – 5.11 mm) and sphericity.
Hunter colour values of mash bean cultivars showed that Mash 1-1 cultivar had darker colour than PU-19 and T-9. Mash bean cultivars had hydration capacity of 0.036 – 0.041 g/seed, swelling capacity of 0.037 – 0.042 mL/seed, cooking time of 35.3 – 42.7 min and solid gruel loss of 11.62 – 13.3%.

Flours produced from selected kidney bean cultivars showed protein, ash, fat, and crude fibre content in the range of 22.3 – 26.7%, 3.0 – 3.5%, 1.6 – 2.0% and 1.4 – 2.1%, respectively. Physico-chemical properties of kidney bean flours like bulk density (0.84 – 0.94 g/mL), swelling index (6.6 – 8.2 g/g), solubility index (32.0 – 36.6%) and syneresis (13.4 – 19.7%) varied significantly (p ≤ 0.05). Pasting properties of kidney bean flours like peak viscosity, breakdown viscosity, setback viscosity and pasting temperature varied correspondingly from 591.0 – 1030.0 cP, 21.3 – 93.3 cP, 383.7 – 750.0 cP and 80.6 – 84.5 °C. Thermal properties of kidney bean flours displayed two endothermic peaks. Peak I which is related to starch gelatinisation had gelatinisation transition temperature from 60.9 – 77.4 °C and ΔH_{gel} from 6.2 – 7.0 J/g, while peak II had transition temperature of 103.6 – 129.6 °C and ΔH of 4.9 – 6.7 J/g. Protein solubility of kidney bean flours showed the lowest solubility in the pH range of 4 – 5 and solubility increased beyond this range. Water absorption capacity of kidney bean flours was in the range of 2.6 – 2.7 g/g. French Yellow flour had significantly (p ≤ 0.05) higher oil absorption capacity than other cultivars under study. Foaming capacity of kidney bean flours in the pH range of 2 – 10 varied from 82.1 – 134.6%. Foam stability measured as half life of foam varied from 0.32 – 12.0 h in the pH range of 2 – 10. Emulsifying properties including emulsifying activity and emulsifying stability in the pH range of 3 – 7 varied from 6.0 – 25.2 m²/g and 15.5 – 73.6 min, respectively. Mash bean flours from selected cultivars showed significant (p ≤ 0.05) differences in ash (2.7 – 3.3%), protein (24.5 – 28.4%), crude fiber (2.7 – 3.4%), swelling index (10.3 – 11.3 g/g) and solubility index (21.4 – 28.4%). Pasting properties of mash bean flours had peak viscosity, breakdown viscosity, setback viscosity and pasting temperature in the range of 2078.7 – 2473.0 cP, 674.3 – 863.7 cP, 588.3 – 804.0 cP and 76.6 – 77.2 °C, respectively. Textural parameters of mash bean flour gels showed cultivar T-9 had higher hardness (18.9 g) and adhesiveness (40.9 gs) than PU-19 and T-9 flours. Thermal properties of mash bean flours displayed transition temperature of 63.5 – 69.5 °C and 105.0 – 136.1 °C and ΔH of 7.3 – 9.3 J/g and 4.2 – 6.1 J/g for peak I and II, respectively. Water and oil absorption capacity of mash bean flours were observed in the range of 2.9 – 3.1 g/g and 2.1 – 2.2 g/g, respectively. Protein solubility profile of flours showed lowest solubility at pH 4 and it progressively increased with increase or decrease in pH. Foaming capacity of flours was...
observed from 67.3 – 130.0 % in the pH range of 2 – 10. Half life of foams varied from 0.27 to > 12 h with higher foam stability at pH 6. Emulsifying activity of mash bean flours varied from 6.0 – 14.5 m²/g and emulsifying stability from 18.8 – 64.6 min.

Starches isolated from kidney bean cultivars had low protein (0.03 – 0.05%), fat (0.1 – 0.6 %) and ash (0.1 %) contents. Yield of isolated starch varied significantly (p ≤ 0.05) from 24.7 – 30.4 % of the seed weight. Starches were subjected to acetylation at 0.04 and 0.08 g acetic anhydride/ g starch. Acetylated kidney bean starches had percent acetyl content and degree of substitution in the range of 0.89 – 2.11 % and 0.03 – 0.08, respectively. Physico-chemical properties of native kidney bean starches like swelling index, solubility index, water absorption capacity, freeze-thaw stability and light transmittance of starch gels increased significantly (p ≤ 0.05) on acetylation. However, syneresis decreased significantly (p ≤ 0.05) on acetylation. Thermal properties of native kidney bean starches displayed gelatinisation transition temperatures from 62.3 – 74.9 °C and ΔH_{gel} 8.6 – 10.2 J/g. Both gelatinisation transition temperatures and ΔH_{gel} decreased significantly on acetylation. Pasting properties of native kidney bean starches like peak viscosity, final viscosity, setback viscosity and pasting temperature were 2074.3 – 2556.3 cP, 3062.0 – 3706.7 cP, 1349.7 – 1802.3 cP and 78.6 – 79.5 °C, respectively. Significant (p ≤ 0.05) differences were observed in pasting properties among the native kidney bean starches. Pasting properties of acetylated kidney bean starches were significantly (p ≤ 0.05) lower than native starches. Textural parameters of starch gels decreased significantly (p ≤ 0.05) on acetylation.

Starches isolated from three mash bean cultivars had also low protein (0.05 – 0.06 %), fat (0.07 – 0.13%) and ash (0.05 – 0.19%) contents. Yield of isolated starch varied significantly (p ≤ 0.05) from 21.4 – 24.4% among the cultivars. Acetylated starches at 0.04 and 0.08 g acetic anhydride/ g starch had percent acetyl content and degree of substitution in the range of 0.80 – 2.09% and 0.03 – 0.08, respectively. Physicochemical properties of native mash bean starches like swelling index, solubility index water absorption capacity, freeze-thaw stability and light transmittance increased significantly on acetylation while syneresis decreased on acetylation. Mash bean starch granules were round, elliptical or oval shaped with mean granule length and width in the range of 17.0 – 17.6 µm and 10.7 – 11.8 µm, respectively. Starch gelatinisation transition temperatures varied from 67.8 – 77.3 °C while ΔH_{gel} varied from 8.9 – 9.9 J/g. Pasting properties of mash bean starches like peak viscosity, final viscosity, setback viscosity and pasting temperature decreased significantly (p ≤ 0.05) from 5109 – 5685 cP, 4769 – 5277 cP, 1239 – 1850 cP and 73.5 – 77.5 °C to 4039 – 4600 cP, 2827 – 3181 cP, 318 – 605 cP and 67.9 – 77.5 °C, respectively.
Protein isolates were obtained from kidney bean and mash bean cultivars by alkali solubilisation and isoelectric precipitation. Protein isolates were modified by papain for 30 and 60 min. Proximate composition of native kidney bean protein isolates displayed significant (p ≤ 0.05) differences in moisture (7.38 – 9.55%), protein (76.96 – 83.96%) and fat (2.53 – 3.44%) content. Yield of protein isolates on seed weight basis varied significantly (p ≤ 0.05) between 16.89 and 20.50% with the lowest yield from Local Red and the highest from Master Bean. Degree of hydrolysis of kidney bean protein isolates varied from 3.13 – 4.70% for 30 min treatment and 6.71 – 8.63% for 60 min treatment with papain. Hunter colour values of native and hydrolysed kidney bean protein isolates revealed ‘L’ values of hydrolysed protein isolates were significantly (p ≤ 0.05) lower than native protein isolates, indicating their darker colour than native protein isolates. Thermal properties of native and hydrolysed kidney bean protein isolates showed two endothermic transitions. Thermal transitions for peak I was from 46.1 – 66.4 °C and enthalpy of denaturation 0.1 – 3.1 J/g. Peak II had thermal transition temperatures between 1001.1 and 118.1 °C and ΔH from 2.4 – 21.5 J/g. Hydrolysed protein isolates had lower transition temperatures and enthalpy of denaturation than native counterparts indicating hydrolysis of proteins. Protein solubility of native and hydrolysed kidney bean isolates showed the lowest solubility of proteins near isoelectric point (pH 5) and it increased on either side of pH 5. Hydrolyzed kidney bean protein isolates had significantly (p ≤ 0.05) higher solubility than native protein isolates. Water and oil absorption capacity of native kidney bean protein isolates was in the range of 5.34 – 5.85 g/g and 5.82 – 6.92 g/g, respectively. Hydrolysed kidney bean protein isolates had significantly higher water (5.48 – 6.30 g/g) and oil (6.97 – 7.85 g/g) absorption capacity than native protein isolates. Emulsifying activity and emulsifying stability of native and hydrolysed protein isolates in the pH range of 3 – 7 varied from 3.2 – 68.2 m²/g and 12.1 – 25.0 min, respectively. Significantly higher emulsifying activity index was observed at pH 7 than at pH 3 and 5 while as significantly higher emulsifying stability index was observed at pH 5 than at pH 3 and 7. Hydrolysed kidney bean protein isolates (30 min hydrolysis time) showed significantly (p ≤ 0.05) higher emulsifying properties. Foaming capacity of native kidney bean protein isolates in the pH range of 2 – 10 varied from 46.0 – 126.0%. Hydrolysed protein isolates had foaming capacity from 54.9 – 151.1 %. Foaming capacity was the lowest at pH 4 and the highest at pH 2 and 10. Hydrolysed protein isolates had generally significantly (p ≤ 0.05) higher foaming capacity than native protein isolates.
Native mash bean protein isolates had moisture, protein and ash in the range of 8.01 – 9.05%, 80.97 – 86.33% and 3.91 – 4.00%, respectively. Yield of protein isolates varied from 18.58 – 19.80% on seed weight basis. Colour value ‘L’ of native mash bean protein isolates was in the range of 72.66 – 76.60. Hydrolysed protein isolates had significantly (p ≤ 0.05) lower ‘L’ value indicating their darker colour than native protein isolates. Mash bean protein isolates had degree of hydrolysis between 3.74 – 4.14% and 6.71 – 8.36% for hydrolysis time of 30 min and 60 min, respectively. Two endothermic transitions were observed in native and hydrolysed mash bean protein isolates. Hydrolysed protein isolates had lower transition temperatures and enthalpy of denaturation than native counterparts indicating hydrolysis of proteins. Protein solubility of native and hydrolysed mash bean protein isolates in the pH range of 2 – 10 was between 4.18 – 92.08% and 5.53 – 99.47%, respectively. The lowest protein solubility was observed between pH 4 – 5 and the highest solubility was observed at pH 10. Significant (p ≤ 0.05) differences in protein solubility were observed between native and hydrolysed protein isolates. Water and oil absorption capacity of native and hydrolysed protein isolates correspondingly increased from 6.05 – 6.74 g/g and 5.45 – 6.29 g/g to 6.66 – 7.96 g/g and 8.69 – 10.20 g/g. Emulsifying activity and stability of native and hydrolysed mash bean protein isolates was in the pH range of 3 – 5 varied from 4.84 – 44.63 m²/g and 14.74 – 88.95 min, respectively. Emulsifying stability was highest at pH 5. Foaming capacity of native and hydrolysed protein isolate varied from 112.33 – 184.46 %. Hydrolysed mash bean protein isolates generally had significantly higher foaming capacity than native protein isolates. Half life of foam varied from 0.49 to > 12 h. The highest foam stability was found at pH 6 than at other pH.

Unleavened flat bread (chapatti) was prepared from wheat-pulse and wheat-pulse protein isolate composite flours. In wheat-pulse composite flours, wheat flour was replaced from 5 – 20% by kidney and mash bean flours while in wheat-pulse protein isolate composite flours replacement was from 1 – 4% by isolates. Water absorption for dough making increased significantly with the addition pulse flour and pulse protein isolates. Sensory evaluation of flat breads produced from wheat-pulse composite flours showed significant decrease in colour, taste, aroma, breakability and overall acceptability score at 15% or higher level of replacement of wheat flour with pulse flour. Sensory score of flat breads from wheat-pulse protein isolate composite flours showed significantly (p ≤ 0.05) lower score than control flat bread for colour, taste and aroma at 4% of replacement. However, there was no effect on chewability, stickiness and overall acceptability of flat breads at 1 – 4% level of replacement. Pasting properties of composite flours and breads produced thereof displayed
significant (p ≤ 0.05) decrease in peak, trough, final and setback viscosity while increase in pasting temperature was observed.

The study can be concluded as under:

- Prior soaking of kidney and mash beans resulted in significant decrease in cooking time.
- Superior cooking properties were observed in kidney bean cv Master bean and mash bean cv T-9.
- Kidney and mash bean flours had good foaming and emulsifying properties.
- Native kidney and mash bean starch gels had high syneresis and setback viscosity while low transmittance and freeze thaw stability reducing their suitability in refrigerated or frozen foods.
- Acetylation improved kidney and mash bean starch gel syneresis, setback viscosity, transmittance and freeze thaw stability.
- Native protein isolates of kidney and mash bean cultivars displayed good functional properties.
- Enzyme hydrolysis by protease for 30 min resulted in improved functional properties of protein isolates.
- Flat bread produced from composite flours containing black gram flour or protein isolate of both pulses reduced staling considerably.

Present study suggests that besides used as whole seeds, kidney and mash beans can be used as functional ingredients in formulated foods in the form of flour, starch and protein isolates. Starch and protein isolates can be modified by acetylation and enzyme hydrolysis, respectively to improve their functionality for wider end use.