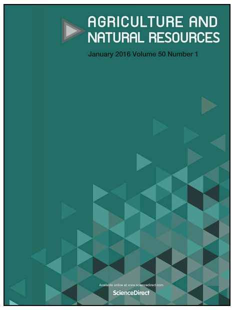

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Snail as Mini-Livestock: Nutritional Potential of Farmed *Pomacea canaliculata* (Ampullariidae)

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Abstract

Amino acids, fatty acids and minerals were investigated in the farmed freshwater snail *Pomacea canaliculata* (Ampullariidae) to understand its nutritional potential as alternative livestock. Snail samples with removed gut content were collected from a local snail farm in the Republic of Korea. Almost all the essential amino acids present in the snail protein satisfied the recommended level for an ideal protein pattern, while methionine was present at a marginal level. The proportion of unsaturated fatty acids (60.5%) was higher than that of saturated fatty acids (39.5%). The ratio of polyunsaturated to monounsaturated fatty acids was 1.08, underscoring the high nutritional quality of the fat content of the species. The most abundant mineral was calcium. The high K/Na ratio (3.9) and the presence of substantial amounts of phosphorus, iron and zinc makes *P. canaliculata* snail meat potentially valuable. Thus, the utilization of under-appreciated nutritious food resources could be helpful in mitigating food security problems and in solving nutritional shortcomings in underprivileged parts of the world.

Introduction

Humans have used snails as food since prehistoric time. Tools to extract the soft parts of land snails through deliberately punched holes in the shells have been identified from human habitation 12,000 years ago in North Africa (Hill et al., 2015) and archaeological evidence from a site in northern Alabama suggested that 2500 BC, the hunter-gatherer population of the New World also consumed gastropods (Schoeninger and Peebles, 1981). Indeed to this day mollusks, including fresh water and terrestrial species of snails, have been acceptable as food in many parts of the world, including New Caledonia Jamaica, Mexico, Taiwan, Formosa, the Philippines (Baby et al., 2010), Thailand and, of course, the Mediterranean countries with in particular, France where “escargots à la bourguignonne” are still regarded a world famous culinary delicacy (Peterson, 2002).

Land snails despite their long history as a human food item, are nevertheless considered a non-conventional wildlife protein source and their consumption, as in the Ishan, Afemai, and Isoko regions of Africa, is often restricted to a certain section of the population and governed by food taboos (Meyer-Rochow, 2009). However, snails are now in the process of becoming a highly relished delicacy, often marketed as ‘Congo meat’, at least in Nigeria (Fagbuaro et al., 2006). If the global population growth rate with an anticipated projection of 9 billion by 2050 is any guide (Bongaarts, 2009; Roberts, 2011), there will be huge pressure on the existing sources of animal protein and a shift to greater use of protein-containing plants can be anticipated. However, from a nutritional point of view, animal proteins possess a higher nutritional value than those of plants, because animal proteins contain larger quantities of essential amino acids (Yen, 2009).

Due to rising costs in producing sufficient amounts of protein-rich food from the major traditional animal sources like beef, pork, sheep, and poultry and because of problems like increased global warming, more widespread shortages of freshwater, deforestation and severe soil erosion (Koneswaran and Nierenberg, 2008; Thornton, 2010; Hedenus et al., 2014) associated with an intensification of livestock rearing, consumers will gradually have to reduce or give up the amount of animal protein they obtain from their food and most likely will need to accept more and more vegetarian sources of protein. However, such a shift, as pointed out above, could come at a cost to the nutritional state of the human population, which is why there is a need to identify alternative, easily available and cheap sources of protein of animal origin. As snails have already been accepted as food in many cultures, they should receive greater attention as a source of alternative animal protein than has happened in the past.

Pomacea canaliculata, a freshwater species of the family Ampullariidae and commonly known as the channeled apple snail or golden apple snail, is a gastropod native to South America, but now also present on all other continents except Antarctica (IUCN, 2017; CABI, 2017). The species is regarded as edible in many parts of the world, including China, and most of Southeast Asia, including Korea (Halwart, 1994, Jung et al., 2012). Generally, snails are handpicked or with the help of a hand net collected from canals, swamps, ponds or flooded paddy fields in the rainy season, while in summer, individuals of this species conceal themselves under dried mud (Setalaphruk and Price, 2007).

The mode of preparation of the species for human consumption includes removing the shell, cleaning in saline water and boiling for several minutes and the consumption of raw or undercooked *P. canaliculata* is not recommended as that is the primary route of infection with *Angiostrongylus cantonensis* causing angiostrongyliasis (Tsai et al., 2001; Lv et al., 2009). Although there are some fragmentary data available on the composition and nutritional value of snails from Africa (Adeyeye and Afolabi, 2004; Fagbuaro et al., 2006; Ogungbenle and Omowole, 2012; Ikauniece et al., 2014), a recent compilation of the proximate nutritional composition of some preferred snail species (Ghosh et al., 2016) and several analyses of the chemical composition of European ‘escargots’, mainly *Helix aspersa,* the vineyard snail (Gomot, 1998), information on *P. canaliculata*’s chemical make-up and comestibility are lacking. Given its extensive culinary acceptance, it was felt that an assessment of the nutritional potential (amino acid, fatty acid and mineral content) of this species was overdue and essential in order to explore the possibility of the snail’s wider use as a base for the formulation of new food/feed products.

Materials and Methods

Sample collection and preparation

Specimens of *P. canaliculata* were obtained packed in a plastic bag (approximately 300 individuals) from a commercial snail farm located at Andong, Republic of Korea (36˚57′ N and 128˚72′ E) during June, 2015. The farm mass-rears *P. canaliculata* primarily for selling as a biological weed control agent in rice paddy field, but also does processing for snail meat for food. The snails are fed commercially available aqua feed with a formula of 17:20:60:1:2 (weight per weight) of protein of fish source, protein of plant source, grains, oil and a mixture of minerals. The nutritional composition of the feed is 23% protein, 3% fat, 10% fiber, 20% soluble carbohydrate, 1% calcium and 1.8% phosphorus. For food processing, about 100 snails (3.5 cm long with 4.5 g) were harvested, washed, steam-heated for 2 min and passed through a press-screw to remove the shell and gut content, then packed and stored at -40 °C. For nutritional analysis, the specimens were taken to the laboratory in a freeze box, and then oven-dried (50 °C for 24 hr), ground to powder and prepared as dry matter (DM) for further analyses. All the solvents and chemicals used in the study were of analytical grade.

Amino acid composition analysis

The amino acid composition was determined using a Sykam Amino Acid analyzer S433 (Sykam GmbH, Eresing, Germany) following the standard method (Association of Official Analytical Chemists, 1990). Tryptophan and methionine, however, are not determinable in their entirety by this method. The ground samples were hydrolyzed in 6 N

HCl for 24 h at 110 °C under a nitrogen atmosphere and then concentrated in a rota-evaporator. The concentrated samples were reconstituted with sample dilution buffer supplied by the manufacturer (0.12N citrate buffer, pH 2.20). The hydrolyzed samples were analyzed for amino acid composition. The operating conditions of the amino acid analyzer were: column: LCA K07/Li (PEEK – column 4.6 × 150 mm); application: physiological; detector: Integrated Dual-Channel Photometer (570nm, 440 nm); detection principle: ninhydrin reaction; and inert gas: N_2. The amino acid score was calculated based on WHO/ FAO /UNU (2007).

Fatty acid composition analysis

Fatty acid composition was analyzed using gas chromatography-flame ionization detection (GC-14B, Shimadzu, Tokyo, Japan) equipped with an SP-2560 column, following the standard method (Korean Food Standard Codex, 2010). The heating rate started from 140 °C to 230 °C for 150 min with five levels of progress (4, 1, 1, 1 and 2 °C /min) to increase detectability. The samples were derivatized into fatty acid methyl esters (FAMEs). Identification and quantification of FAMEs were accomplished by comparing the retention times of peaks with those of pure standards purchased from Sigma (Yongin, Republic of Korea) and analyzed under the same conditions.

The results were expressed as a percentage of individual fatty acids in the lipid fraction. The atherogenic index (AI) and thrombogenic index (TI) were calculated according to the standard formulas (Ulbricht and Southgate, 1991) shown in Equations 1 and 2:

$$\mathrm{AI} = \frac{(\mathrm{C12{:}0} + 4 \text{ x } \mathrm{C14{:}0} + \mathrm{C16{:}0})}{[\sum \mathrm{MUFA} + \sum \mathrm{PUFA}\ (n-6) + (n-3)]} \qquad (1)$$

$$\mathrm{TI} = \frac{(\mathrm{C14{:}0} + \mathrm{C16{:}0} + \mathrm{C18{:}0})}{[0.5 \text{ x } \sum \mathrm{MUFA} + 0.5 \text{ x } \sum \mathrm{PUFA}\ (n-6) + 3 \text{ x } \sum \mathrm{PUFA}\ (n-3) + \{\frac{n-3}{n-6}\}]} \qquad (2)$$

where PUFA is polyunsaturated fatty acids and MUFA is monounsaturated fatty acids

Mineral analyses

Minerals were analyzed following the standard method (Korean Food Standard Codex, 2010). Dried powder samples were digested with nitric and hydrochloric acid (1:3) at 200 °C for 30 min. Each sample was then filtered using Whatman filter paper (0.45 micron) and stored in washed glass vials before analysis could commence. The mineral contents were analyzed using an inductively-coupled plasma-optical emission spectrophotometer (ICP-OES 720 series; Agilent; Santa Clara, CA, USA).

Results

The amino acid compositions of *P. canaliculata* proteins are shown in Table 1. The total protein content (48.5% based on dry weight) was determined by summing the individual amino acids including ammonia. Almost all the essential amino acids were present, albeit with little recovery of methionine and tryptophan. The proportion of essential amino acids was 39.7% whereas the proportion of non-essential amino acids was 60.3%. Among the essential amino acids two solely ketogenic amino acids predominated (leucine followed by lysine). By comparing the essential amino acid content of a sample protein with that of a standard protein's chemical score, tryptophan was identified as limiting while methionine was present at a marginal level. On the other hand, glutamic acid predominated followed by arginine and aspartic acid among the non-essential amino acids. Comparison of snail essential amino acids with the recommended protein pattern and with conventional protein sources are represented in Fig. 1 and Fig. 2, respectively.

The fatty acid composition of *P. canaliculata* is presented in Table 2, with 16 different fatty acids being determined. The proportion of unsaturated fatty acids (60.5%) was higher than that of saturated fatty acids (39.5%). Among the unsaturated fatty acids of *P. canaliculata*, the proportion of polyunsaturated fatty acids (PUFA) was higher than that of the monounsaturated ones (MUFA). Of the saturated fatty acids (SFA), palmitic acid was the most abundant followed by stearic acid; the dominating MUFA and PUFA constituents were oleic and linoleic acid, respectively. The parameters used to assess the quality of fat (PUFA/SFA, n-6/n-3, AI and TI) indicated the snail fat was of good dietetic quality.

The results of the mineral content analyses are provided in Table 3. Five macro-minerals and four micro-minerals were identified. The most abundant mineral was calcium, but *P. canaliculata* can also be regarded as a suitable and substantial source of phosphorus, iron and zinc. A comparison of the snail's minerals content with other conventional food sources is presented in Fig. 3.

Discussion

Questions related to the global food security situation of the future are dominated by worries that protein demands might sooner or later outstrip protein supplies, resulting in nutritional deficiencies and health problems (Müller and Krawinkel, 2005). Since for carbohydrates and fats such consequences are not envisaged, it is the protein availability that receives the brunt of attention in the search of alternative food resources.

Protein content and availability

The freshwater snail, *P. canaliculata* had a high protein content of 48.5% dry mass. Dominant essential amino acids present were leucine and lysine. The quality of protein as related to human nutritional requirements depends upon the amino acid composition (de Guevara et al., 1995). The presence of a high amount of ketogenic acid was in agreement with studies on uncultured snails like *Helix pomatia, Achachatina marginata* (Adeyeye and Afolabi, 2004; Ikauniece et al., 2014) or *Limicoria* sp. and *Achatina achatina* (Adeyeye and Afolabi, 2004)., A high leucine component was also reported in the range 5–10% from sea fish and carp (Kaushik, 1998; Mohanty et al. 2014). Lysine was the most abundant essential amino -acid in *Helix aspersa* (Cagiltay et al., 2011). Lysine, which synthesizes carnitine that is required for the transportation of fatty acid into mitochondria for β-oxidation, has received comparatively greater attention because it is limiting in the rice, maize, wheat and cassava-based diets prevalent in many parts of the world (Chavan and Kadam, 1989). The lysine content of *P. canaliculata* was higher than that reported for *A. achatina* and *A. marginata* but somewhat less than that of *Limicolaria* sp. (Adeyeye and Afolabi, 2004). Different lysine contents (2.9–4.8%) were reported from freshwater fish (Mohanty et al., 2014), with higher amounts (9-16%) from marine and cold-water fish (Zuraini et al., 2006; Mohanty et al. 2014). Ketogenetic diets are gaining more attention in clinical nutrition to benefit cancer therapy (Tennant et al., 2010; Schimdt et al., 2011) as well as in diet for weight loss (Dashti et al., 2004).

Valine and isoleucine—two branched chain amino acids (BCAAs)—were present in substantial amounts in the protein fraction of *P. canaliculata*. Isoleucine is required for muscle formation and proper growth (Charlton, 2006). Patients on hemodialysis suffering from chronic renal failure have a low plasma level of BCAAs—leucine, isoleucine and valine (Vuzelov et al., 1999). The proportions of valine and isoleucine in the snails in the current study were higher than those reported for *T. putitora* (3.8 and 3.7%, respectively) but lower than in most fresh water fish generally consumed as food (Mohanty et al., 2014). Histidine is important as the precursor of histamine, which is released from cells as a part of allergic reactions and plays an important role in the dilation and contraction of certain blood vessels (White, 1990; Ashina et al., 2015). With the exception of tryptophan, the protein content of *P. canaliculata* satisfies the levels of essential amino acids of the recommended protein pattern by WHO/ FAO /UNU (2007), reaching a methionine score of 62.5% (10 instead of ideal value 16 mg/g protein) as shown in Fig. 1. Cysteine and methionine are two sulfur-containing amino acids. Though it is known that cysteine can spare the partial requirement of methionine, there is no indication of the portion of total sulfur-containing amino acids which can be met by cysteine (FAO/WHO/UNU, 1985). However, effective utilization of dietary proteins requires an appropriate balance between essential and nonessential amino acids as well as other nitrogen containing compounds. Arginine, essential for infants (Wu et al., 2004), is present in *P. canaliculata* along with other nonessential amino acids. The essential amino acids content of the apple snail showed comparable if not higher levels in comparison with published reports of conventional protein sources of both plant and animal origin as detailed in Fig. 2 (US Department of Agriculture, 2015).

Fat content and availability

Regarding the proportions of unsaturated and saturated fatty acids, reports exist for *Helix aspersa*, *H. aspersa maxima*, and *H. pomatia* (Ozogul et al., 2005; Milinsk et al., 2006; Cagiltay et al., 2011). Among SFAs, the proportion of palmitic acid predominated which was in agreement with the reports for different species of marine fish such as *Thunnus albacares*, *Euthynnus affinis* and *S. commersoni*, brackish water fish like *Lates calcarifer*, *Mugil cepahalus* and *Etroplus suratensis* and a few fresh water fish like *L. rohita* and *H. fossilis* (Mohanty et al., 2016). Similarly, oleic acid was found in abundance among the MUFAs and this is the case for most fish in different habitats (Mohanty et al., 2016). Assessing the qualities of fat is a complex issue. High levels of SFAs are not desirable, because of their linkage to atherosclerotic disorders (Grundy, 1997). The AI indicates the relationship between the sum of the main saturated fatty acid and that of the main classes of unsaturated fatty acids, the former being considered pro-atherogenic (Ulbricht and Southgate, 1991). Saturated (lauric, myristic and palmitic) acids have the highest atherogenic potential and of these, the capacity of myristic acid to increase cholesterol levels is four times greater than the other two (Ulbricht and Southgate, 1991). The AI of the lipid fraction of the golden apple snail was 0.55, which was lower than that reported for coconut oil (13–20), palm kernel oil (7), cocoa butter (0.7) and comparable to if not less than animal meat (0.5 – 1) (Bobe et al., 2004) indicating less risk of cardiovascular disease. TI indicates the tendency to form clots in the blood vessels. It is defined as the relationship between prothrombogenic (saturated) and anti-thrombogenic (MUFA and PUFA) fatty acids. A higher TI indicates the potential risk of coronary heart disease (Attia et al., 2017). A positive correlation has been reported between the intake of n-3 fatty acid (especially docosahexaenoic acid; DHA) and cognitive function, visual acuity and overall brain development (Swanson et al., 2012). However, in general, The DHA proportion of *P. canaliculata* fat was lower than in most fish species which often offer low cost DHA (Hoffman et al., 2009; Mohanty et al., 2016). As the snail contained a substantial proportion of n-3 PUFA (19.9%), it had a lower TI value indicating high fat quality. The TI value of the snail (0.4) was lower than for lamb meat (1.87) (Morbidini et al., 2001) and a little higher than that reported for sea bream and sea bass (Grigorakis, 2007). Evidence suggests that the consumption of excessive amounts of n-6 fatty acid and a very high n-6/n-3 ratio promotes the pathogenesis of many ailments including cardiovascular, cancer, inflammatory and autoimmune diseases, whereas an increased level of n-3 and thus a low n-6/n-3 ratio exerts suppressive effects (Simopoulos, 2002). By comparison, the n-6/n-3 ratio of *P. canaliculata* was 1.11, which was much less, even undercutting the value of 5:1–10:1 recommended by WHO/FAO (1994).

However, not all SFAs elevate cholesterol levels and only lauric, myristic and palmitic acids have been shown to be involved while stearic acid has actually been shown to lower low-density lipoprotein (LDL) cholesterol (Mensink, 2005). In snails generally, and for *P. canaliculata* in particular, the levels of both lauric and myristic acid were lower than those reported from conventional animal meats. The PUFA/SFA ratio is one of the major parameters currently used to assess the nutritional quality of the lipid fraction of food. Nutritional guidelines recommend that the PUFA/SFA ratio should be above 0.4 (FAO/WHO, 2003). In *P. canaliculata*, this ratio was determined as 1.08, underscoring the high nutritional quality of the fat content of the species.

Mineral content and availability

Calcium, an essential mineral, plays vital roles by virtue of its phosphate salts in neuromuscular function, many enzyme-mediated processes, excretion, blood clotting and bone and tooth formation (Higdon and Drake, 2012). Calcium plays important roles in regulating muscle contraction, Ca^{2+} triggers muscle contraction by reaction with regulatory protein (Szent-Györgyi, 1975). Compared with other minerals of nutritional importance, calcium is economically relatively inefficient (Rafferty and Heaney, 2008). Sodium, moreover, raises calcium excretion, because it competes with calcium for reabsorption in the renal tubules (Sellmeyer et al., 2002). Generally milk, milk products and animal meats are considered food sources rich in calcium, but they are often inaccessible to a large section of the world's population. Infants and lactating women require more calcium and suboptimal intakes may hinder normal growth and manifest osteoporosis in older people, especially post-menopausal women (Higdon and Drake, 2012). A high level of calcium was found in *P. canaliculata* and was much higher than that reported in other studies on different species of snails (Fagbuaro et al., 2006; Babalola and Akinsoyinu, 2009; Adgoke et al., 2010; Baby et al., 2010), but Gomot (1998) reported a high Ca content in the foot of *Helix pomatia* (4580 mg/100 g). The consumption of snail meat could mitigate calcium deficiencies. The high K/Na ratio (3.9) makes *P. canaliculata* snail meat potentially valuable. Low potassium levels in humans, have been associated with a variety of physiological disorders of the respiratory tract and kidneys and with hypertension (Cohn et al., 2000).

Furthermore, *P. canaliculata* was found to be a good source of iron and zinc, both being important elements for human health: zinc as an essential component of large numbers (more than 300) of enzymes and iron mainly as a component of hemoglobin and involved in respiratory processes (Higdon and Drake, 2012). Iron deficiency results from an inadequate supply of iron to cells following depletion of the body's reserve which leads to microcytic anemia (Kotze et al., 2009). Under such conditions, because of the low iron store in the body, hemoglobin synthesis and red blood cell formation are severely impaired (Kotze et al., 2009). The recommended dietary allowance (RDA) for iron is 8 mg/d for men and postmenopausal women, and 27 mg/d for pregnant women (Food and Nutrition Board, 2001). The most vulnerable sections of a population affected by iron deficiency are infants at the weaning stage, children and women of child bearing age (Burke et al., 2014), who could benefit most from the consumption of *P. canaliculata* products. Copper is an essential trace element for humans. The ability of copper to easily accept and donate electrons by shifting between the cuprous (Cu^{+1}) and cupric (Cu^{+2}) forms explains its important role in oxidation-reduction (redox) reactions and as a scavenging free radical (Linder and Hazegh-Azam, 1996). In addition, copper together with zinc is a structural component of the antioxidant enzyme superoxide dismutase (Turnland, 2006). Assuming good bioavailability, minerals contained in snail meat could be expected to mitigate the risks of calcium, zinc and iron deficiency disorders. Overall, with the exception of sodium, *P. canaliculata* contained all other minerals at higher levels compared to conventional foods of animal origin.

Despite the obvious benefits of humans using snails as an animal nutritional source, snail farming remains one of the least recognized aspects of micro-livestock production let alone macro-livestock. Although numerous snail species are accepted as food in many parts of the world, reliable and systematic data on snails pertaining to identification and description of species, consumption rates, seasonal availability, nutritional profile and medicinal uses (Bonnemain, 2005) are scarce. Moreover, they are often directly harvested from the wild and this practice bears a potential threat to their existence with unknown ecological consequences unknown. Thus, the establishment of “snaileries” (snail farms) providing high nutritional value with little investment and requiring labor with no strenuous physical exertion could promote this under-appreciated source of nutritious food and thereby help to solve nutritional shortcomings and even unemployment in some countries or underprivileged districts.

Conflict of interest

The authors declare no conflict of interest.

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Table 1 Amino acid composition of *P. canaliculata*

Amino acid	g/100 g dry matter	% of total amino acids
Valine*	2.1	4.3
Isoleucine*	2	4.1
Leucine*	4	8.2
Lysine*	3.3	6.8
Tyrosine†	2.2	4.5
Threonine*	2.3	4.7
Phenylalanine*	2.1	4.3
Histidine*	0.8	1.6
Methionine*	0.5	1
Tryptophan*	0.1	0.2
Arginine	4.4	9.1
Aspartic acid	4.1	8.5
Serine	2.4	4.9
Glutamic acid	8.4	17.3
Glycine	2.8	5.8
Alanine	2.9	5.9

Cystine	0.4	0.8
Proline	2.3	4.7
Norleucine	1.3	2.7
Taurine	0.01	0.02
Ammonia	0.1	0.2

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[*] = essential amino acid for humans.

[†] = conditional essential amino acid for humans.

Table 2 Fatty acid composition of *P. canaliculata*

Fatty acid	mg/100 g dry matter	% of total amino acids
Lauric acid C12:0	3.7	0.5
Myristic acid C14:0	21.6	3.1
Pentadecanoic acid C15:0	3.1	0.4
Palmitic acid C16:0	144.8	20.5
Margaric acid C17:0	8.6	1.2
Stearic acid C18:0	63.3	9
Behenic acid C22:0	17.6	2.5
Lignoceric acid C24:0	16.8	2.4
Subtotal	279.5	39.5
Hexadecenoic acid C16:1	3.8	0.5
Oleic acid C18:1	64.5	9.1
Eicosenoic acid C20:1	57.1	8.1
Subtotal	125.4	17.7
Linoleic acid C18:2 n-6	146	20.6
Linolenic acid C18:3 n-3	6.1	0.9

Eicosadienoic acid C20:2 n-6	17.6	2.5
Eicosatrienoic acid C20:3 n-3	125	17.7
DHA n-3	7.6	1.1
Subtotal	302.3	42.7
Polyunsaturated fatty acids/ saturated fatty acids	1.08	
n-6/n-3	1.11	
Atherogenic index	0.55	
Thrombogenic index	0.41	

Table 3 Minerals content of *P. canaliculata*

Minerals	mg/100 g dry matter
Calcium	5161.2
Magnesium	56.9
Sodium	93.4
Potassium	364.4
Phosphorus	550.4
Iron	45.5
Copper	7.1
Zinc	10.1
Manganese	2.0

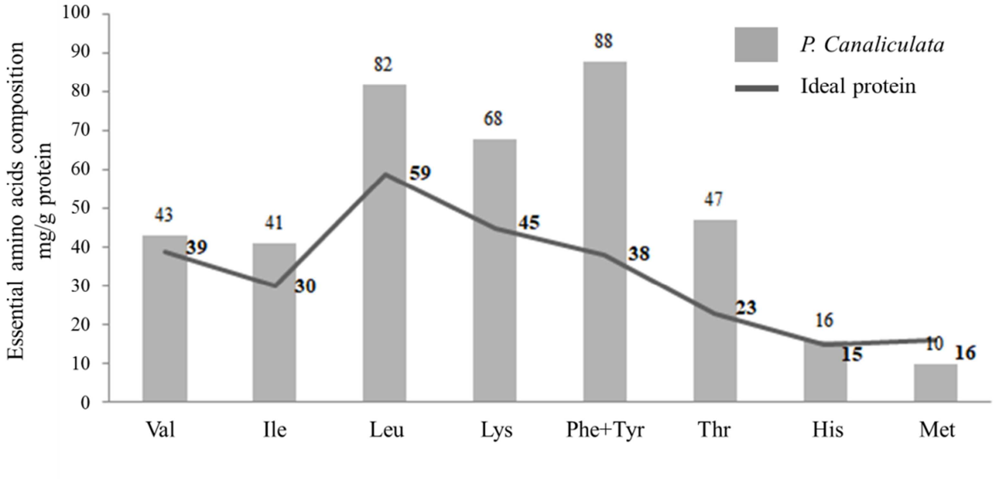

Fig. 1 Comparison of essential amino acids composition between *P. canaliculata* and recommended protein pattern based on FAO/WHO/UNU (2007), where Val = valine, Ile = isoleucine, Leu = leucine, Lys = lysine, Phe = phenylalanine, Tyr = tyrosine, Thr = threonine, His = histidine, Met = methionine

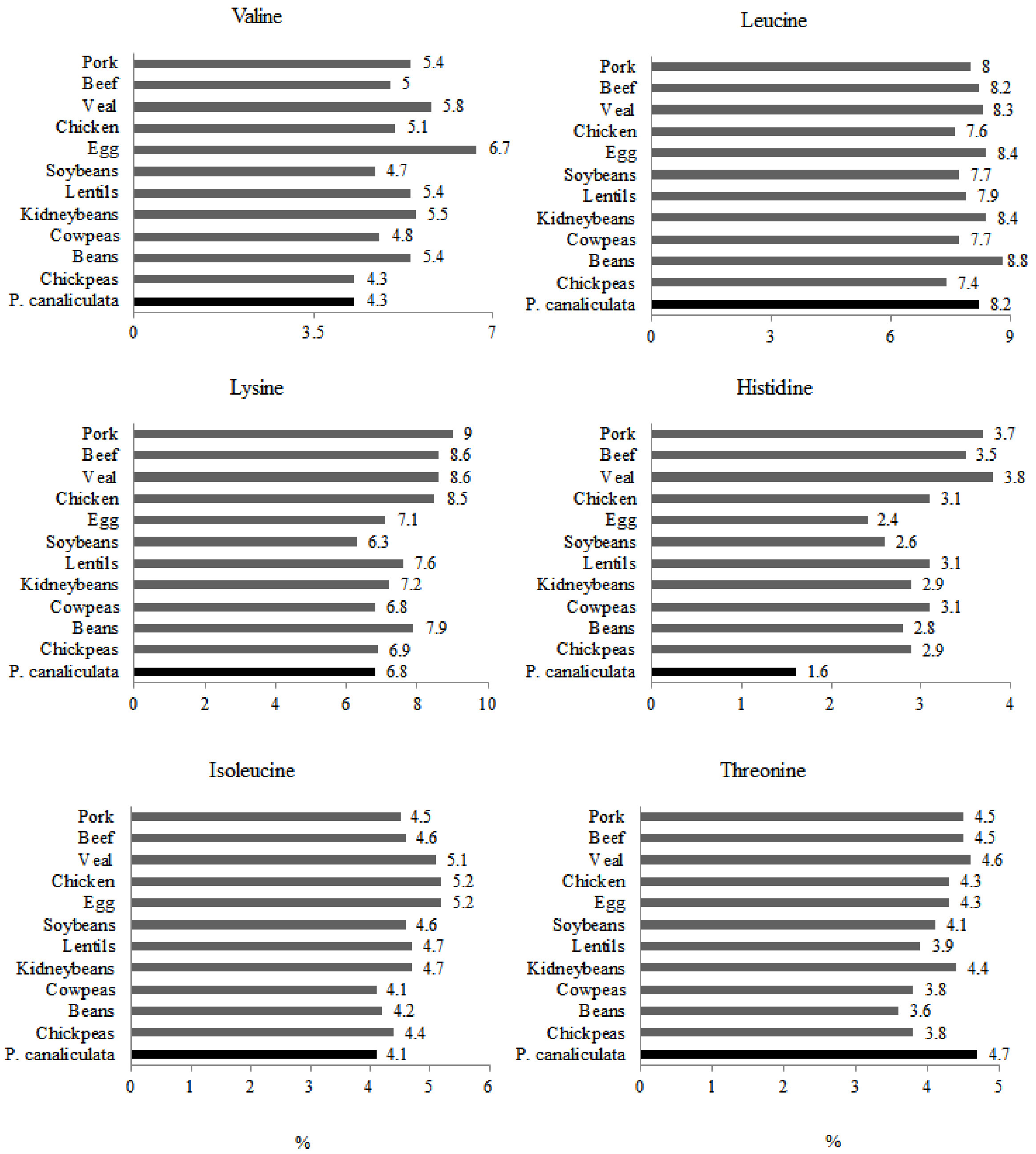

Fig. 2 Comparison of some essential amino acids among *P. canaliculata* and conventional protein sources (data other than *P. canaliculata* adopted from US Department of Agriculture, 2015)

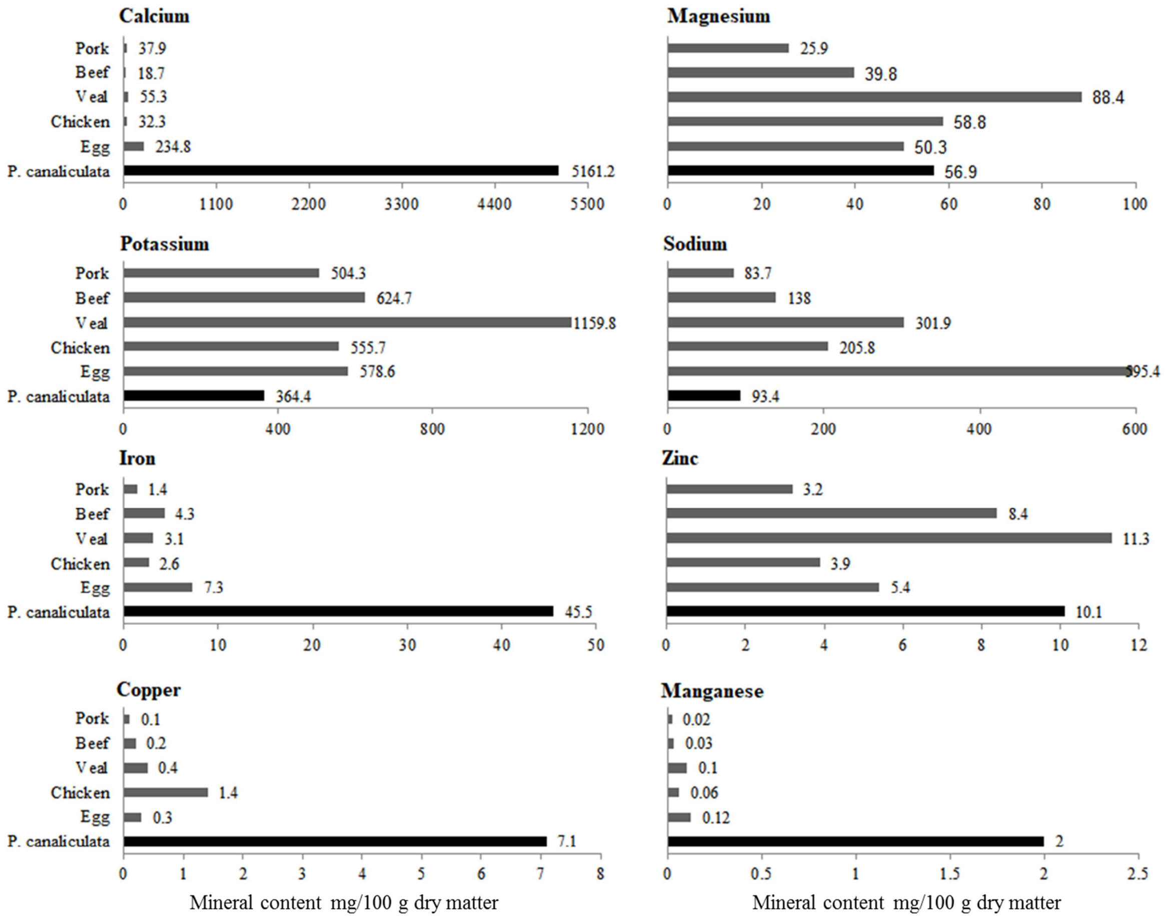

Fig. 3 Mineral content of *P. canaliculata* compared with conventional food sources (data other than *P. canaliculata* adopted from US Department of Agriculture, 2015)