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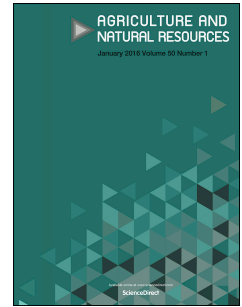
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4 **Snail as Mini-Livestock: Nutritional Potential of Farmed *Pomacea canaliculata***

5 **(Ampullariidae)**

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33 Abstract

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

47

48 Introduction

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

59 Land snails despite their long history as a human food item, are nevertheless
60 considered a non-conventional wildlife protein source and their consumption, as in the Ishan,
61 Afemai, and Isoko regions of Africa, is often restricted to a certain section of the population
62 and governed by food taboos (Meyer-Rochow, 2009). However, snails are now in the process

63 of becoming a highly relished delicacy, often marketed as ‘Congo meat’, at least in Nigeria
64 (Fagbuaro et al., 2006). If the global population growth rate with an anticipated projection of
65 9 billion by 2050 is any guide (Bongaarts, 2009; Roberts, 2011), there will be huge pressure
66 on the existing sources of animal protein and a shift to greater use of protein-containing
67 plants can be anticipated. However, from a nutritional point of view, animal proteins possess
68 a higher nutritional value than those of plants, because animal proteins contain larger
69 quantities of essential amino acids (Yen, 2009).

70 Due to rising costs in producing sufficient amounts of protein-rich food from the
71 major traditional animal sources like beef, pork, sheep, and poultry and because of problems
72 like increased global warming, more widespread shortages of freshwater, deforestation and
73 severe soil erosion (Koneswaran and Nierenberg, 2008; Thornton, 2010; Hedenus et al.,
74 2014) associated with an intensification of livestock rearing, consumers will gradually have
75 to reduce or give up the amount of animal protein they obtain from their food and most likely
76 will need to accept more and more vegetarian sources of protein. However, such a shift, as
77 pointed out above, could come at a cost to the nutritional state of the human population,
78 which is why there is a need to identify alternative, easily available and cheap sources of
79 protein of animal origin. As snails have already been accepted as food in many cultures, they
80 should receive greater attention as a source of alternative animal protein than has happened in
81 the past.

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

90 The mode of preparation of the species for human consumption includes removing the
91 shell, cleaning in saline water and boiling for several minutes and the consumption of raw or
92 undercooked *P. canaliculata* is not recommended as that is the primary route of infection
93 with *Angiostrongylus cantonensis* causing angiostrongyliasis (Tsai et al., 2001; Lv et al.,

94 2009). Although there are some fragmentary data available on the composition and
95 nutritional value of snails from Africa (Adeyeye and Afolabi, 2004; Fagbuaro et al., 2006;
96 Ogunbenle and Omowole, 2012; Ikauniece et al., 2014), a recent compilation of the
97 proximate nutritional composition of some preferred snail species (Ghosh et al., 2016) and
98 several analyses of the chemical composition of European ‘escargots’, mainly *Helix aspersa*,
99 the vineyard snail (Gomot, 1998), information on *P. canaliculata*’s chemical make-up and
100 comestibility are lacking. Given its extensive culinary acceptance, it was felt that an
101 assessment of the nutritional potential (amino acid, fatty acid and mineral content) of this
102 species was overdue and essential in order to explore the possibility of the snail’s wider use
103 as a base for the formulation of new food/feed products.

104 **Materials and Methods**

105 *Sample collection and preparation*

106 Specimens of *P. canaliculata* were obtained packed in a plastic bag (approximately
107 300 individuals) from a commercial snail farm located at Andong, Republic of Korea (36°57'
108 N and 128°72' E) during June, 2015. The farm mass-rears *P. canaliculata* primarily for
109 selling as a biological weed control agent in rice paddy field, but also does processing for
110 snail meat for food. The snails are fed commercially available aqua feed with a formula of
111 17:20:60:1:2 (weight per weight) of protein of fish source, protein of plant source, grains, oil
112 and a mixture of minerals. The nutritional composition of the feed is 23% protein, 3% fat,
113 10% fiber, 20% soluble carbohydrate, 1% calcium and 1.8% phosphorus. For food processing,
114 about 100 snails (3.5 cm long with 4.5 g) were harvested, washed, steam-heated for 2 min
115 and passed through a press-screw to remove the shell and gut content, then packed and stored
116 at -40 °C. For nutritional analysis, the specimens were taken to the laboratory in a freeze box,
117 and then oven-dried (50 °C for 24 hr), ground to powder and prepared as dry matter (DM) for
118 further analyses. All the solvents and chemicals used in the study were of analytical grade.

119 *Amino acid composition analysis*

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

124 HCl for 24 h at 110 °C under a nitrogen atmosphere and then concentrated in a rota-
 125 evaporator. The concentrated samples were reconstituted with sample dilution buffer supplied
 126 by the manufacturer (0.12N citrate buffer, pH 2.20). The hydrolyzed samples were analyzed
 127 for amino acid composition. The operating conditions of the amino acid analyzer were:
 128 column: LCA K07/Li (PEEK – column 4.6 × 150 mm); application: physiological; detector:
 129 Integrated Dual-Channel Photometer (570nm, 440 nm); detection principle: ninhydrin
 130 reaction; and inert gas: N₂. The amino acid score was calculated based on WHO/ FAO /UNU
 131 (2007).

132 *Fatty acid composition analysis*

133 Fatty acid composition was analyzed using gas chromatography-flame ionization
 134 detection (GC-14B, Shimadzu, Tokyo, Japan) equipped with an SP-2560 column, following
 135 the standard method (Korean Food Standard Codex, 2010). The heating rate started from
 136 140 °C to 230 °C for 150 min with five levels of progress (4, 1, 1, 1 and 2 °C /min) to
 137 increase detectability. The samples were derivatized into fatty acid methyl esters (FAMES).
 138 Identification and quantification of FAMES were accomplished by comparing the retention
 139 times of peaks with those of pure standards purchased from Sigma (Yongin, Republic of
 140 Korea) and analyzed under the same conditions.

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

$$145 \quad AI = \frac{(C12:0+4 \times C14:0+C16:0)}{[\sum MUFA+ \sum PUFA (n-6)+(n-3)]} \quad (1)$$

$$147 \quad TI = \frac{(C14:0+C16:0+C18:0)}{[0.5 \times \sum MUFA+0.5 \times \sum PUFA (n-6)+ 3 \times \sum PUFA (n-3)+\{\frac{n-3}{n-6}\}]} \quad (2)$$

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

151 *Mineral analyses*

152 Minerals were analyzed following the standard method (Korean Food Standard
 153 Codex, 2010). Dried powder samples were digested with nitric and hydrochloric acid (1:3) at
 154 200 °C for 30 min. Each sample was then filtered using Whatman filter paper (0.45 micron)

155 and stored in washed glass vials before analysis could commence. The mineral contents were
156 analyzed using an inductively-coupled plasma-optical emission spectrophotometer (ICP-OES
157 720 series; Agilent; Santa Clara, CA, USA).

158 **Results**

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

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

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

184 **Discussion**

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

190 *Protein content and availability*

191 The freshwater snail, *P. canaliculata* had a high protein content of 48.5% dry mass.
192 Dominant essential amino acids present were leucine and lysine. The quality of protein as
193 related to human nutritional requirements depends upon the amino acid composition (de
194 Guevara et al., 1995). The presence of a high amount of ketogenic acid was in agreement
195 with studies on uncultured snails like *Helix pomatia*, *Achachatina marginata* (Adeyeye and
196 Afolabi, 2004; Ikaunieca et al., 2014) or *Limicoria* sp. and *Achatina achatina* (Adeyeye and
197 Afolabi, 2004). A high leucine component was also reported in the range 5–10% from sea
198 fish and carp (Kaushik, 1998; Mohanty et al. 2014). Lysine was the most abundant essential
199 amino -acid in *Helix aspersa* (Cagiltay et al., 2011). Lysine, which synthesizes carnitine that
200 is required for the transportation of fatty acid into mitochondria for β -oxidation, has received
201 comparatively greater attention because it is limiting in the rice, maize, wheat and cassava-
202 based diets prevalent in many parts of the world (Chavan and Kadam, 1989). The lysine
203 content of *P. canaliculata* was higher than that reported for *A. achatina* and *A. marginata* but
204 somewhat less than that of *Limicolaria* sp. (Adeyeye and Afolabi, 2004). Different lysine
205 contents (2.9–4.8%) were reported from freshwater fish (Mohanty et al., 2014), with higher
206 amounts (9–16%) from marine and cold-water fish (Zuraini et al., 2006; Mohanty et al. 2014).
207 Ketogenetic diets are gaining more attention in clinical nutrition to benefit cancer therapy
208 (Tennant et al., 2010; Schimdt et al., 2011) as well as in diet for weight loss (Dashti et al.,
209 2004).

210 Valine and isoleucine—two branched chain amino acids (BCAAs)—were present in
211 substantial amounts in the protein fraction of *P. canaliculata*. Isoleucine is required for
212 muscle formation and proper growth (Charlton, 2006). Patients on hemodialysis suffering
213 from chronic renal failure have a low plasma level of BCAAs—leucine, isoleucine and valine
214 (Vuzelov et al., 1999). The proportions of valine and isoleucine in the snails in the current
215 study were higher than those reported for *T. putitora* (3.8 and 3.7%, respectively) but lower

216 than in most fresh water fish generally consumed as food (Mohanty et al., 2014). Histidine is
217 important as the precursor of histamine, which is released from cells as a part of allergic
218 reactions and plays an important role in the dilation and contraction of certain blood vessels
219 (White, 1990; Ashina et al., 2015). With the exception of tryptophan, the protein content of
220 *P. canaliculata* satisfies the levels of essential amino acids of the recommended protein
221 pattern by WHO/ FAO /UNU (2007), reaching a methionine score of 62.5% (10 instead of
222 ideal value 16 mg/g protein) as shown in Fig. 1. Cysteine and methionine are two sulfur-
223 containing amino acids. Though it is known that cysteine can spare the partial requirement of
224 methionine, there is no indication of the portion of total sulfur-containing amino acids which
225 can be met by cysteine (FAO/WHO/UNU, 1985). However, effective utilization of dietary
226 proteins requires an appropriate balance between essential and nonessential amino acids as
227 well as other nitrogen containing compounds. Arginine, essential for infants (Wu et al.,
228 2004), is present in *P. canaliculata* along with other nonessential amino acids. The essential
229 amino acids content of the apple snail showed comparable if not higher levels in comparison
230 with published reports of conventional protein sources of both plant and animal origin as
231 detailed in Fig. 2 (US Department of Agriculture, 2015).

232 *Fat content and availability*

233 Regarding the proportions of unsaturated and saturated fatty acids, reports exist for
234 *Helix aspersa*, *H. aspersa maxima*, and *H. pomatia* (Ozogul et al., 2005; Milinsk et al., 2006;
235 Cagiltay et al., 2011). Among SFAs, the proportion of palmitic acid predominated which was
236 in agreement with the reports for different species of marine fish such as *Thunnus albacares*,
237 *Euthynnus affinis* and *S. commersoni*, brackish water fish like *Lates calcarifer*, *Mugil*
238 *cephalus* and *Etroplus suratensis* and a few fresh water fish like *L. rohita* and *H. fossilis*
239 (Mohanty et al., 2016). Similarly, oleic acid was found in abundance among the MUFAs and
240 this is the case for most fish in different habitats (Mohanty et al., 2016). Assessing the
241 qualities of fat is a complex issue. High levels of SFAs are not desirable, because of their
242 linkage to atherosclerotic disorders (Grundy, 1997). The AI indicates the relationship
243 between the sum of the main saturated fatty acid and that of the main classes of unsaturated
244 fatty acids, the former being considered pro-atherogenic (Ulbricht and Southgate, 1991).
245 Saturated (lauric, myristic and palmitic) acids have the highest atherogenic potential and of
246 these, the capacity of myristic acid to increase cholesterol levels is four times greater than the
247 other two (Ulbricht and Southgate, 1991). The AI of the lipid fraction of the golden apple

248 snail was 0.55, which was lower than that reported for coconut oil (13–20), palm kernel oil
249 (7), cocoa butter (0.7) and comparable to if not less than animal meat (0.5 – 1) (Bobe et al.,
250 2004) indicating less risk of cardiovascular disease. TI indicates the tendency to form clots in
251 the blood vessels. It is defined as the relationship between prothrombogenic (saturated) and
252 anti-thrombogenic (MUFA and PUFA) fatty acids. A higher TI indicates the potential risk of
253 coronary heart disease (Attia et al., 2017). A positive correlation has been reported between
254 the intake of n-3 fatty acid (especially docosahexaenoic acid; DHA) and cognitive function,
255 visual acuity and overall brain development (Swanson et al., 2012). However, in general, The
256 DHA proportion of *P. canaliculata* fat was lower than in most fish species which often offer
257 low cost DHA (Hoffman et al., 2009; Mohanty et al., 2016). As the snail contained a
258 substantial proportion of n-3 PUFA (19.9%), it had a lower TI value indicating high fat
259 quality. The TI value of the snail (0.4) was lower than for lamb meat (1.87) (Morbidini et al.,
260 2001) and a little higher than that reported for sea bream and sea bass (Grigorakis, 2007).
261 Evidence suggests that the consumption of excessive amounts of n-6 fatty acid and a very
262 high n-6/n-3 ratio promotes the pathogenesis of many ailments including cardiovascular,
263 cancer, inflammatory and autoimmune diseases, whereas an increased level of n-3 and thus a
264 low n-6/n-3 ratio exerts suppressive effects (Simopoulos, 2002). By comparison, the n-6/n-3
265 ratio of *P. canaliculata* was 1.11, which was much less, even undercutting the value of 5:1–
266 10:1 recommended by WHO/FAO (1994).

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

276

277 *Mineral content and availability*

278 Calcium, an essential mineral, plays vital roles by virtue of its phosphate salts in
279 neuromuscular function, many enzyme-mediated processes, excretion, blood clotting and

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

297 Furthermore, *P. canaliculata* was found to be a good source of iron and zinc, both
298 being important elements for human health: zinc as an essential component of large numbers
299 (more than 300) of enzymes and iron mainly as a component of hemoglobin and involved in
300 respiratory processes (Higdon and Drake, 2012). Iron deficiency results from an inadequate
301 supply of iron to cells following depletion of the body's reserve which leads to microcytic
302 anemia (Kotze et al., 2009). Under such conditions, because of the low iron store in the body,
303 hemoglobin synthesis and red blood cell formation are severely impaired (Kotze et al., 2009).
304 The recommended dietary allowance (RDA) for iron is 8 mg/d for men and postmenopausal
305 women, and 27 mg/d for pregnant women (Food and Nutrition Board, 2001). The most
306 vulnerable sections of a population affected by iron deficiency are infants at the weaning
307 stage, children and women of child bearing age (Burke et al., 2014), who could benefit most
308 from the consumption of *P. canaliculata* products. Copper is an essential trace element for
309 humans. The ability of copper to easily accept and donate electrons by shifting between the
310 cuprous (Cu^{+1}) and cupric (Cu^{+2}) forms explains its important role in oxidation-reduction
311 (redox) reactions and as a scavenging free radical (Linder and Hazegh-Azam, 1996). In

312 addition, copper together with zinc is a structural component of the antioxidant enzyme
313 superoxide dismutase (Turnland, 2006). Assuming good bioavailability, minerals contained
314 in snail meat could be expected to mitigate the risks of calcium, zinc and iron deficiency
315 disorders. Overall, with the exception of sodium, *P. canaliculata* contained all other minerals
316 at higher levels compared to conventional foods of animal origin.

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

328

329 **Conflict of interest**

330 The authors declare no conflict of interest.

331

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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

545 * = essential amino acid for humans.

546 † = conditional essential amino acid for humans.

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553 **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
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Polyunsaturated fatty acids/ saturated fatty acids		1.08
n-6/n-3		1.11
Atherogenic index		0.55
Thrombogenic index		0.41
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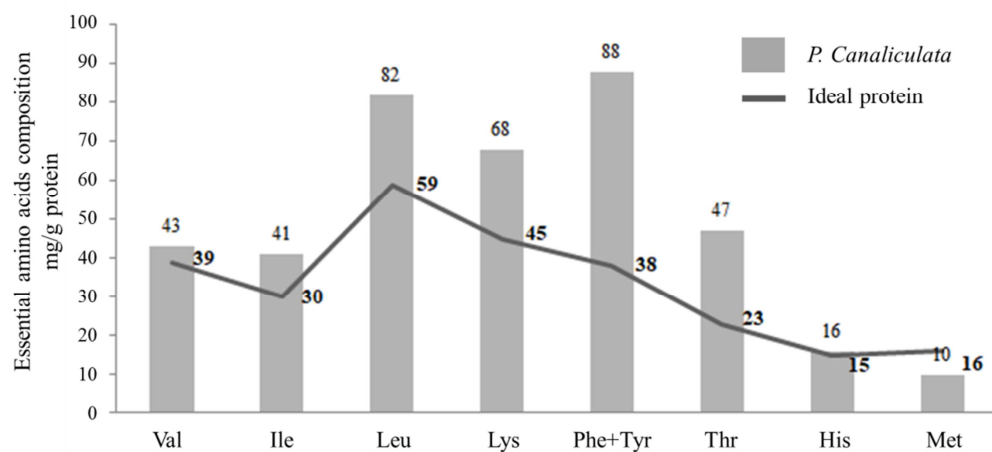
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558 **Table 3** Minerals content of *P. canaliculata*

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

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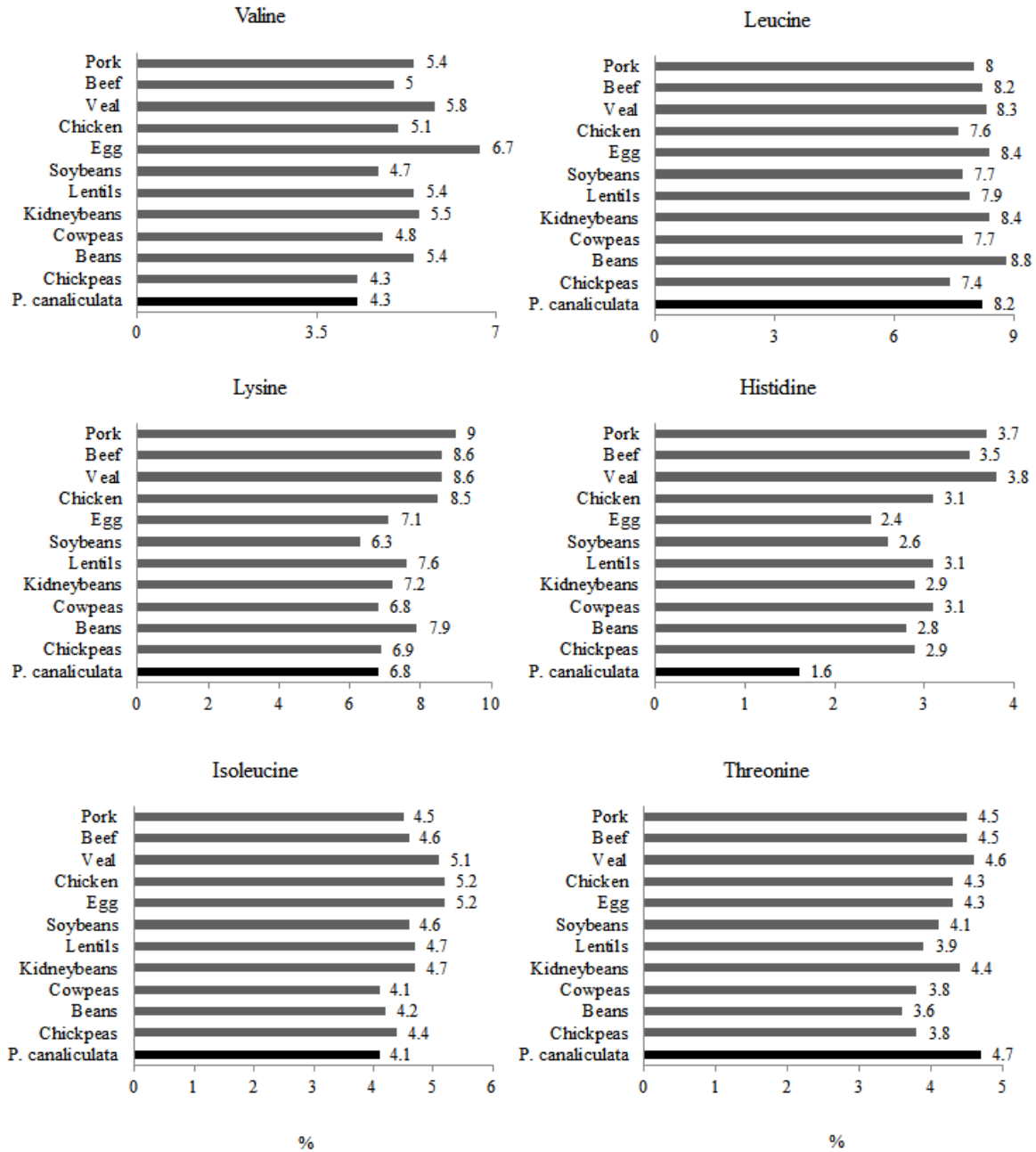
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563 **Fig. 1** Comparison of essential amino acids composition between *P. canaliculata* and
564 recommended protein pattern based on FAO/WHO/UNU (2007), where Val = valine, Ile
565 = isoleucine, Leu = leucine, Lys = lysine, Phe = phenylalanine, Tyr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

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

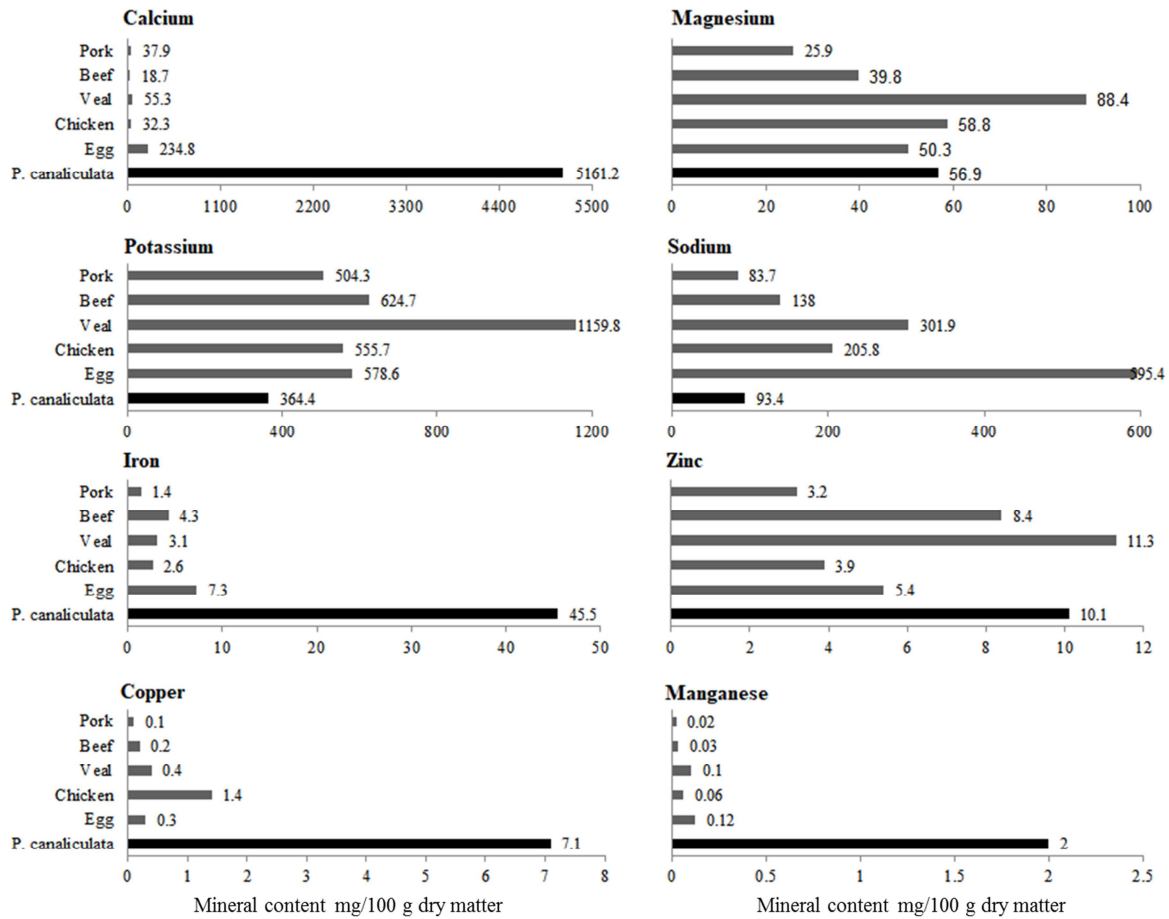
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580 **Fig. 3** Mineral content of *P. canaliculata* compared with conventional food sources (data581 other than *P. canaliculata* adopted from US Department of Agriculture, 2015)

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