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14-Nov-2020

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Critical Reviews in Food Science and Nutrition - Invitation to Review Manuscript ID BFSN-2020-5985

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The above manuscript, entitled "New trends in speciality coffees - "The digested coffees"." has been submitted to Critical Reviews in Food Science and Nutrition.

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Sincerely,

Dr Clydesdale

Beverly Kokoski, Critical Reviews in Food Science and Nutrition Editorial Office
fergc@foodsci.umass.edu, bak324@gmail.com

MANUSCRIPT DETAILS

TITLE: New trends in speciality coffees - "The digested coffees".

ABSTRACT: Specialty coffee has gained immense popularity for its unique flavor and improved quality. There are large varieties of coffee setting the trend every day due to the widened demand. Still, specialty coffee holds its place for its distinct processing inside the animal digestive system. Specialty coffees are also considered the most expensive known coffee varieties with novelty in processing which leads to limited availability and less productivity. The digested coffee's uniqueness and rarity led to higher consumer demand, which paved the way for animal abuse in captivity and production of fake authenticity to tackle the increased market requirement. In the context of coffee processing through conventional methods, the application of enzymes and microbes has brought about an improvement in coffee fermentation. Much research has been focused on the isolation of microbial cultures from the animal excreta and gastrointestinal tract. This review emphasizes the types of specialty coffee, its uniqueness compared to the traditional varieties, the bio-processing method of specialty coffee inside the animal gut and its taste profile.

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Wed, Dec 9, 2020 at 6:43 AM

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Best regards,

DS

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I think that would be fine
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Best regards
Fergus

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Fergus

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Dr Fergus Clydesdale

Critical Reviews in Food Science and Nutrition

New trends in speciality coffees - "The digested coffees".

Reviewer Affiliation

Lampung University, Agricultural Engineering

Manuscript ID:

BFSN-2020-5985

Manuscript Type

Review

Keywords

Fermentation, bio-processing, enzymes, gastrointestinal tract

Date Submitted:

13-Oct-2020

Date Assigned:

16-Nov-2020

Date Review Returned:

20-Dec-2020

Author(s)

RAVEENDRAN, ASHIKA

Murthy, Pushpa

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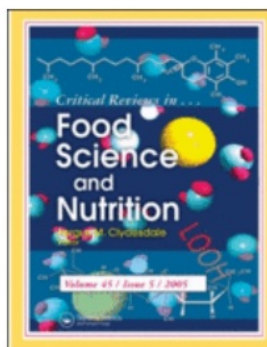
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New trends in speciality coffees - "The digested coffees".

Journal:	Critical Reviews in Food Science and Nutrition
Manuscript ID:	BFSN-2020-5985
Manuscript Type:	Review
Date Submitted by the Author:	13-Oct-2020
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Keywords:	Fermentation, bio-processing, enzymes, gastrointestinal tract

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New trends in speciality coffees - “The digested coffees”.

1 Ashika Raveendran^{a,b}, Pushpa S. Murthy^{a,*}

2 ³¹
3 ^a *Department of Spices, and Flavour Science,*

4 *CSIR-Central Food Technological Research Institute under, Mysore-570020, New Delhi, India*

5

6 ²⁰
7 ^b *Academy of Scientific & Innovative Research (AcSIR),*

8 *Ghaziabad 201002, Uttar Pradesh, India*

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22 *Corresponding Author: Dr. Pushpa S. Murthy

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24 *Tel. +91 821 2512352; Fax: + 91 821 2517233*

25 *Email: pushpa@cftri.res.in*

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24 **Abstract**

25 Specialty coffee has gained immense popularity for its unique flavor and improved quality. There
26 are large varieties of coffee setting the trend every day due to the widened demand. Still, specialty
27 coffee holds its place for its distinct processing inside the animal digestive system. Specialty
28 coffees are also considered the most expensive known coffee varieties with novelty in processing
29 which leads to limited availability and less productivity. The digested coffee's uniqueness and
30 rarity led to higher consumer demand, which paved the way for animal abuse in captivity and
31 production of fake authenticity to tackle the increased market requirement. In the context of coffee
32 processing through conventional methods, the application of enzymes and microbes has brought
33 about an improvement in coffee fermentation. Much research has been focused on the isolation of
34 microbial cultures from the animal excreta and gastrointestinal tract. This review emphasizes the
35 types of specialty coffee, its uniqueness compared to the traditional varieties, the bio-processing
36 method of specialty coffee inside the animal gut and its taste profile.

37 **Keywords:** Fermentation, bio-processing, enzymes, gastrointestinal tract

47 Introduction

48 Coffee is one of the most globally appreciated beverages with a consumption of more
49 than 500 billion coffee cups per year. Coffee prevails to be the second-largest commodity
50 in market value exceeding a global production of 9 million tonnes next to petroleum (De
51 Carvalho Neto et al. 2018). It is an integral part of the human diet and ²³ is one of the most
52 popular beverages consumed worldwide. Coffee has found to possess several health
53 benefits (Youjin and Giovannucci 2014; Pimpley et al. 2020). Coffee based products also
54 include refreshments (cola), pharmaceuticals and cosmetics other than brews.

55 The extensive manufacturer and trader of coffee is Brazil. For the period of
56 2020-2021 world's coffee production forecast 9.1 million bags (60 kg per bag) which are
57 ²⁸ higher to the previous year record of 176.1 million in Brazil (United States Department of
58 Agriculture (USDA) 2020). According to the reports, Brazil is the supreme leader in
59 coffee production for the period of 2014-2018. Brazil is an exclusive breeder of diverse
60 and variant coffees which spans the most customary coffee class. The subsequent chief
61 producer for this period was Vietnam. Columbia remains to be the world's third coffee
62 producer and their coffee varieties are familiar for its intense aroma. Indonesia favors for
63 both the growth and market development of coffee because of its unique geographical
64 location. Indonesia also plays an important role in coffee production with Robusta coffee
65 being the major coffee produce in the country. Indonesian coffee production is expected
66 to decline from 10.7 million bags in 2019-2020 to 10.3 million bags in 2020-2021
67 (United States Department of Agriculture (USDA) 2020). This reduction in coffee
68 production is due to the delayed precipitation that negatively affected Robusta coffee
69 yield. Different varieties of speciality coffees are also produced in small quantities in this
70 country. Indonesian Arabica coffee is one of the world's strongest coffees, but it has
71 ²² limited production. ²² Kopi luwak is one of the most popular and expensive Indonesian

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72 coffee variety that is produced and traded exclusively, depending on the civet cat. In the
73 coffee production rankings Indonesia is followed by Honduras, Ethiopia, India, Uganda,
74 Peru and Mexico (Slavova and Georgieva 2019).

75 Different layers are developed on the coffee cherries upon ripening, which are
76 exocarp, mesocarp and endocarp that keep the seed intact. Mucilage is the part of
77 mesocarp of coffee cherries. All the coffee fermentation methods to-date aims to
78 eliminate the mucilage layer that has abundant polysaccharides (pectin) and reduce the
79 water content of coffee beans. The pectic mucilaginous coat in beans causes hindrance to
80 its rapid drying that can favor microbial growths. Nevertheless, fermentation also has a
81 beneficial influence on the quality traits of coffee when it is carried out in controlled
82 conditions (Haile and Kang 2019). Presently, there are three major kinds of post-harvest
83 system that are used for coffee processing: dry, wet and semi-dry process. The processing
84 of coffee may affect its flavor profile. Certain speciality coffees have a unique processing
85 inside the gut of animal.

86 The demand for coffee has steadily increased over the past decades, and this
87 necessitates consumers on the production of different and novel varieties of coffee with
88 the best quality. Speciality coffees are the highest graded coffees in terms of availability
89 and its distinct flavor. Of the many varieties grown worldwide, a few varieties have
90 achieved a special reputation and notoriety based upon their rarity and overall flavor.
91 Among them, Jamaican Blue Mountain and Hawaiian Kona coffee have been recognized
92 for its remarkable flavor. Hence they are branded as superior coffees (Jumhawan et al.
93 2015). The Jamaican Blue Mountain and Tanzanian Peaberry are notable for their
94 premium price (Marcone 2004). The digested coffees have its special place among these
95 varieties for its unique processing, limited availability and smooth taste devoid of the
96 bitterness compared to regular coffees.

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6 98 **Types of Animal Fermented Speciality Coffees**

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8 99 **Civet Coffee (Kopi Luwak)**

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12 100 Kopi and Luwak are the Indonesian words for coffee and civet, respectively. Luwak Kopi
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14 101 is made from coffee berries eaten by the Asian palm civet (*Paradoxurus*
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16 102 *hermaphroditus*), a small mammal native to southern and northern Asia. In 1945, Kopi
17 103 Luwak coffee had its origin in the Dutch coffee plantation estates and the local people
18
19 104 received profit from the estate managers in return for these unusual beans (Marcone
20
21 105 2004). Civet coffee is very hard to find. It is estimated that about 250-500 kg of civet
22
23 106 coffee is obtained from wild civet coffee every year. The price for a single cup of civet
24
25 107 coffee costs \$35-\$80 and one pound bag of beans costs \$100-\$600. (Muzaifa et al. 2018).
26
27 108 Kopi Luwak is considered to be the world's most expensive coffee with an estimated
28
29 109 annual production of 127 kg with price tag of up to \$200-400 per kg and it is known as
30
31 110 the rarest coffee. These are widely available in international markets including Europe,
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33 111 USA and Asian countries such as Japan, Taiwan and South Korea (D 'Cruze et al. 2014).
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43 113 *Classification*

44 114 Kingdom: *Animalia*

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46 115 Phylum: *Chordata*

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49 116 Class: *Mammalia*

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52 117 Order: *Carnivora*

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55 118 Suborder: *Feliformia*

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120 Genus: *Paradoxurus*

121 Species: *hermaphrodite* (Patou et.al. 2008)

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123 *Chemical composition of Luwak coffee*

124 There are few reports on the chemical composition of Luwak coffee. The fermentation
125 process inside the gastrointestinal tract leads to lowering of caffeine content in both
126 Robusta Luwak and Arabica Luwak coffees and also there is development of distinctive
127 odor. The roasting process decreases the volume of caffeine by a minimal proportion. In
128 addition to caffeine, the protein content was also found to be low, indicating that the
129 proteins were partially broken down and leached out within the animal's gastrointestinal
130 tract during the digestion process. There is some evidence that the fermentation in
131 Luwak's gastrointestinal tract improved its quality because of the ideal temperature (240-
132 260°C). In addition to that, it is assisted by the bacteria in the gastrointestinal tract and
133 coffee bean proteins are degraded by proteolytic enzyme in the gut. This gives rise to
134 short peptides and free amino acids that provides a unique taste to Luwak coffee. After
135 processing, in gastrointestinal tract, there is an increase in coffee's lipid content compared
136 to original coffee. Higher lipid content provides delicious taste (Mahendradatta et al.
137 2012).

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139 *Sensory attributes of Luwak coffee*

140 Sensory analysis is an essential method for the characterizing the various coffee types. In
141 the coffee sector, sensory assessment is known as cupping. The volatile compounds

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4 142 accounts for the aromatic properties, while the non-volatile compounds describes the
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6 143 acidity of the coffee (Fisk et al. 2012).

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10 145 *Aroma*

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12 146 The quality of coffee is expressed in terms of fragrance, which refers to the aromatic
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14 147 evaluation of dry coffee grounds, while the aroma is also described from the coffee
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16 148 liquor. The coffee aroma formation is an intricate process. The aroma involves the
17
18 149 composite mixture of volatile compounds such as sulfur compounds, pyridines,
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20 150 pyrazines, pyrazoles, aldehydes, furans, oxazole, ketones and phenols developed during
21
22 151 the process of roasting (Buffo and Cardelli-Perreira 2004; Toci and Farah 2008). Wild
23
24 152 civet coffee incorporates a rich aroma, flavor and aftertaste, good balance but sometimes
25
26 153 accompanies an earthy aroma. The aroma of civet coffee is influenced by the kind of food
27
28 154 eaten by the civet. The wild civet consumes several types of food in the forest, while the
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30 155 fruits such as guava and papaya are most frequently provided for feeding caged civet, and
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32 156 fascinatingly the aroma of the fruit appears on the processed coffee (Muzaiifa et al. 2018).

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39 158 *Flavor*

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42 159 In a roasted and ground coffee, the flavor compounds rely on several factors, two of
43
44 160 which are of significant relevance. First, the variety and quality of green coffee; sets the
45
46 161 stage for the later production of flavor during roasting. Second, the roasting process
47
48 162 which unlocks the flavor potential of green coffee beans and produces the coffee taste
49
50 163 that is highly appreciated by coffee connoisseur worldwide (Lindinger et al. 2008).
51
52 164 Although the reports on the sensory quality of civet coffee are limited, there has been
53
54 165 information on the comparative studies on wild and caged civet. (Muzaiifa et al.
55
56 166 2018). The flavor and aroma profile of luwak coffee has been described (Table 1).

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5 168 *Physical Quality*

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8 169 Civet feces constitute the excretion of the digestive civet phase. It is usually semi-solid
9
10
11 170 with a mucus coat. The appearance of feces differs considerably (i.e., form, colour, scale,
12
13 171 texture) depending on the diet consumed by the civet (Muzaifa et al. 2018).

14
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16
17 173 *Process of Luwak coffee production*

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19 6
20 174 The civet climbs on coffee trees and instinctively selects coffee cherries. During
21
22 175 digestion, the coffee pericarp is completely digested and the beans are excreted
23
24 176 (Jumhawan et al. 2013). Ripe berries are subjected to Luwak's digestive tract for
25
26 177 fermentation that takes approximately 12 hours. The defecated beans are collected and
27
28 178 cleaned. These coffee beans are further dried at appropriate temperature for particular
29
30 179 duration of time. Subsequently, the husk is removed then the coffee beans are sorted and
31
32 180 dried. The green beans are roasted and ground to obtain the premium Luwak coffee.
33
34 181 Conventional coffee processing requires long periods of processing that can be met with
35
36 182 the fermentation inside the animal's gastrointestinal tract (Figure 1) (Mahendradatta et al.
37
38 183 2012).

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46 185 *Ivory Coffee (Elephant dung coffee)*

47
48 186 Black Ivory coffee or Elephant dung coffee is a coffee brand exclusively provided by the
49
50 187 Black Ivory Coffee Company in Thailand. The trademark taste of this coffee has been
51
52 188 portrayed as "smooth without the harshness of standard coffee" with a cost of \$1800 per
53
54 189 kg. 4 Black Ivory Coffee is one among the world's highly-priced coffee. 4 It has a limited
55
56 190 productivity of approximately 200 kg per year (Thammarat et al. 2018). The company
57
58 191 suggests a requirement of approximately 33 kg of coffee for the production of 1 kg of

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192 Black Ivory Coffee. The best cherries of Thai Arabica are selected for the production of
193 this exotic variety. The coffee beans are fed to the elephants along with other foods, such
194 as rice, banana and tamarind in order to obtain this variety of coffee.

195

196 *Classification*

197 Kingdom: *Animalia*

198 Phylum: *Chordata*

199 Class: *Mammalia*

200 Order: *Proboscidea*

201 Family: *Elephantidae*

202 Genus: *Elephas*

203 Species: *maximus*

204 (Choudhury et al. 2008)

205

206 *Chemical composition of Ivory coffee*

207 The comparative studies on Ivory coffee and the conventional coffee have reported a
208 similar profile i.e., both containing same 78 tentative volatile compounds. These
209 compounds were further classified into 13 chemical classes. There were no unique
210 compounds identified from elephant dung coffee. Therefore the ²⁹comparisons of the
211 ⁴compound peak areas were investigated. Following this, four compounds were identified
212 as discriminant markers: 3-methyl-1-butanol, 2-methyl-1-butanol, 2-furfurylfuran and 3-

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213 penten-2-one. These are useful for the authentication and quality control of Ivory coffee
214 (Thammarat et al. 2018).

215 Haile, Bae, and Kang (2020) have reported that elephant dung coffee has higher
216 Total Phenol content than coffee beans obtained from conventional processing. The
217 increase in total phenol content of Ivory coffee compared to the regular coffee might be
218 associated with its distinct processing methods. The coffee beans are subjected to various
219 acids, alcohols and digestive enzymes inside the elephant's digestive tract that may have
220 contributed to the degradation of the complex molecules of coffee beans and increased
221 the phenolic contents during the extraction time. The total phenol content was higher in
222 slightly roasted Ivory coffee beans than those roasted at various temperatures. The total
223 flavonoid content was improved in both green and roasted elephant dung coffee
224 compared than conventional processed coffee beans. The elephant dung coffee had
225 significantly higher total tannin content compared to regular coffee beans.

226 227 *Antioxidant activity*

228 Coffee is considered as rich in antioxidants for nearly two-thirds of the population
229 (Sridevi, Giridhar, and Ravishankar 2011). A comparative study on different processing
230 methods was conducted, which suggested that the bio-processing method inside the
231 elephant gut gives a better outcome on the antioxidant activity of coffee. Regarding the
232 green coffee beans, the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity
233 of elephant dung coffee beans was higher as compared to that of the dry processed and
234 wet processed coffee beans. Usually, the green coffee beans had higher DPPH activity
235 (Haile, Bae, and Kang 2020).

236 237 *Process of Ivory coffee production*

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238 Ivory coffee is usually procured from Arabica coffees, which are collected from the feces
239 of Asian elephants (*Elephas maximus*). The digestion and fermentation of coffee cherries
240 occur inside the elephant's gastrointestinal tract for 12 to 70 hours, along with several
241 other food ingredients. Then the coffee is washed, dried, hulled and sorted to choose the
242 perfect green beans (Thammarat et al. 2018).

243

244 *Jacu Coffee*

245 Jacu coffee is one of the most remarkable and claims to fame Brazilian coffees obtained
246 from Jacu bird (Guan). These coffees are newly emerging specialty coffees within
247 the block. Jacu bird is indigenous to the Atlantic rainforest. It is a frugivorous (fruit
248 feeding) bird, yet additionally benefits from sprouts, leaves, insects and grains. It
249 consumes coffee cherries as they are sweet with high sugar content. Despite the fact that
250 they inhabit in the woods, it also moves to the open field for foods. The seeds of the
251 coffee cherries are ingested are defecated intact. It is the most expensive coffees of
252 Espirito Santo State that is estimated to a cost of \$112.29 per kg (Malacarne et al. 2017).

253

254 *Classification*

255 Kingdom: *Animalia*

256 Phylum: *Chordata*

257 Class: *Aves*

258 Order: *Galliformes*

259 Family: *Cracidae*

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3 260 Genus: *Penelope*
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6 261 Species: *obscura*
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12 263 **Gut Microbes in Speciality Coffee**

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16 264 Few investigations focus on the array of microbes present in the gut flora of animals
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18 265 fermenting specialty coffees, making them prominent. Lactic acid bacteria existing in the
19
20 266 alimentary canal may contribute in the fermentation of coffee as they have enzyme
21
22 267 activity (mainly protease and pectinase). The ability of microorganisms to break down
23
24 268 proteins and pectins indicates that the isolates could serve as a potential starter in coffee
25
26 269 fermentation. Protein degradation yields peptides and some free amino acids, while pectin
27
28 270 hydrolysis yields some simple sugars. The results of the degradation of these two
29
30 271 components can affect the taste of coffee during roasting (Muzaiifa et al. 2019).
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35 272 An insight into the civet's gastrointestinal tract indicates *Enterobacteriaceae* as
36
37 273 the most prominent culturable bacteria in Luwak's alimentary canal. Apart from this, the
38
39 274 genera such as *Escherichia*, *Bacillus*, *Pseudomonas*, *Lactobacillus*, *Pantoea*,
40
41 275 *Ochrobactrum* and *Kocuria* are also observed in cultures. (Suhandono et al. 2016) The
42
43 276 microbes also having the ability of caffeine-degradation are isolated from the feces of
44
45 277 Luwak includes *Methylobacterium populi*, *Klebsiella quasipneumoniae*, *Raoultella*
46
47 278 *ornithinolytica*, *Stenotrophomonas chelatiphaga*. (Iswanto et al. 2019)
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53 54 55 280 **Demerits of Speciality Coffee** 56 57 58 59 60

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3 281 The speciality coffee has been noted to have a particular attribute of nutty and fishy
4
5 282 aroma which is a drawback of digested coffees. Luwak farming is a solution for its
6
7 283 limited production, but this method has been blocked due to animal ethical rights. The
8
9 284 prominence and rising need for Luwak coffee have contributed contrarily to adultrants
10
11 285 promising its origin. Unfortunately, there are still no convenient quality control measures
12
13 286 to test this aspect. The biological process inside the Asian civet or Luwak intestine during
14
15 287 fermentation still seems unclear. Apart from that, there are limited scientific reports on
16
17 288 the quality of Luwak coffee. Since these coffees are developed only at unique locations,
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19 289 the studies concerning these coffee productions are limited for both wild and farming
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21 290 methods
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31 **Conclusion**

32 293 In conclusion, this review focuses on specialty coffee, its types, processing methods of
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34 294 specialty coffee, the sensory analysis and the demerits of specialty coffee. Coffee has
35
36 295 been a popular beverage for ages. Its popularity is setting trends every day with newer
37
38 296 varieties. Coffee has a long-standing history and researches have investigated its varying
39
40 297 aspects for long. The recent focus has been on the specialty coffees due to its unique
41
42 298 processing. The processing of coffee has contributed to its peculiar flavor. The
43
44 299 conventional coffee processing methods primarily includes dry processing, wet
45
46 300 processing and semi-dry processing. Furthermore, there have been numerous attempts to
47
48 301 use enzymes in coffee processing to aid in the fermentation of coffee. In specialty coffee,
49
50 302 especially in digested coffee, the coffee cherries pass through the gastrointestinal tract.
51
52 303 This fermentation method has acknowledged this variety to a great extent and placed it as
53
54 304 one of the premium and exotic coffees worldwide, raising the coffee market.
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306 **Future Prospects**

307 Specialty coffee processing can bring about an improvement to the existing coffee
308 marketing. The high cost of animal processed coffee has been due to its processing
309 methods that have not been completely understood. The sensory analysis of these
310 digested coffees is still limited. Since the animal digested coffee passed through the
311 animal's gut and excreted, the coffee beans need to undergo processes further to eliminate
312 the contaminants and the fishy aroma. The limited production of these varieties had urged
313 the coffee producers for animal farming, which leads to ethical concerns. There are many
314 forgeries to this coffee variety for its limited availability, as there is less scientific studies
315 on determining its quality. There are also many other kinds of digested coffees emerging,
316 which need to be explored.

317 Specialty coffee processing still is an unexplored field that provides immense scope for
318 the researchers. Luwak coffee has limited scientific evidence and some aspects still are
319 not exploited. The processing of speciality coffee is still unclear. Other types of speciality
320 coffees such as Jacu coffee, the emerging monkey parchment coffee and few other
321 digested coffees need more scientific evidence. These speciality coffees could be further
322 investigated with newer technologies, which provide a promising future to exotic
323 varieties.

324

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327

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329

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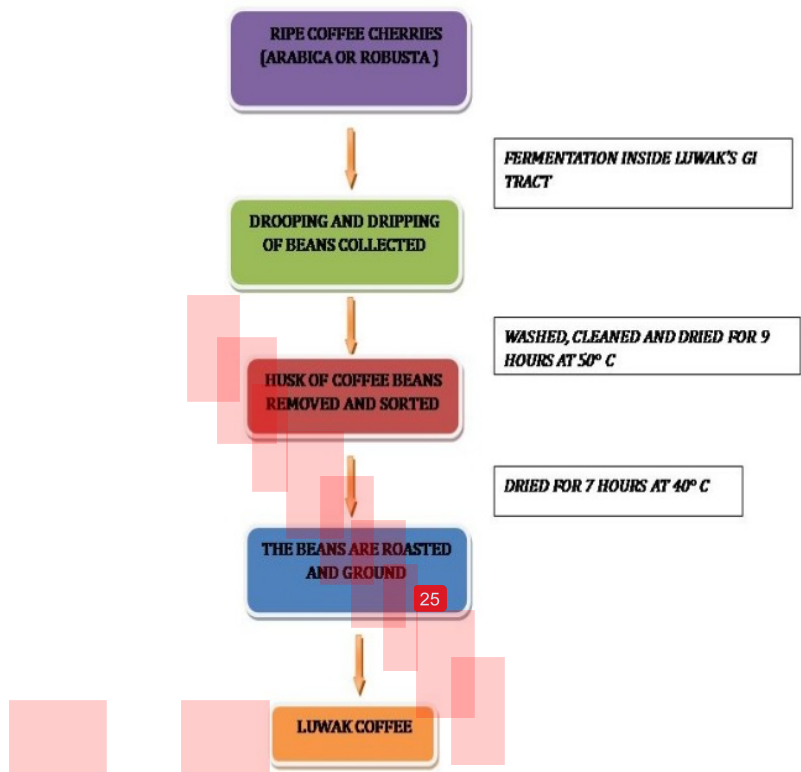


Figure 1. Flow diagram for Kopi Luwak processing (Mahendradatta et al. 2012)

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Table 1. Aroma and flavor description of civet coffee

Luwak Coffee	Reference
Fishy	(Muzaifa et al. 2018)
Nutty	
Herby	
Creamy	
Grassy-tobacco like	
Mint	
Sweet	(Patria, Abubakar, and Muzaifa 2018).
Chocolaty	
Slightly earthy	

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