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A comparative study of the physico-chemical properties of prominent cocoa bean in Southern Vietnam

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Abstract

Fourteen prominent cocoa varieties commonly cultivated in the central highlands of Vietnam were characterized based on their physico-chemical properties. The mass ratio and bean size (value index), as well as proximate composition (total protein, ash, moisture, and lipid content) of the dried fermented cocoa beans, were measured using the AOAC methods. The results showed that cocoa bean variety TD8 recorded the largest size (1.5 g of mass, 25.02 mm of length, 14.28 mm of width and 7.96 mm of thickness). The moisture content of the sampled cocoa beans was in the range of 5.64 and 6.99 (%wb) and the ash content measured between 3.67 and 2.47 (%wb). Noticeably, the fat content of seven (TD1, TD2, TD5, TD11, TD12, TD13, TD14) out of the fourteen beans sampled was over 50%. Thus these varieties have great potential for industrialized cultivation and cocoa breeding projects.

1. Introduction

Cocoa beans are harvested from cocoa trees (*Theobroma cacao* L.) (Lecumberri *et al*., 2007) and provide enormous benefits to producing countries by boosting their economies as well as providing good nutrition to consumers (Aremu *et al.*, 1995; Wood and Lass, 2008; Efombagn *et al*., 2009; Lâm, Vanlerberghe, Toan *et al*., 2015). Cocoa-originated food has long been consumed as far back as the eighteenth century (Lecumberri *et al*., 2007).

Currently, Vietnam focuses mainly on investment in producing cocoa beans for exportation since cocoa beans of Vietnamese origin are now of good quality and as such able to compete with cocoa beans from other top-exporting countries (Lâm, Nguyễn, Nguyễn *et al*., 2015). Cocoa trees are well adapted to the climate and soil of southern Vietnam (Phạm, 2009; Trần and Hồ, 2011). The highest bean yield has since been reported from the Mekong Delta and Central Highlands of Vietnam. Most of the recent studies have focused on the breeding and selection of high-yield cocoa varieties in Ben Tre and Can Tho (Trần *et al*., 2010; Trần and Hồ, 2011). Other studies that are conducted on the quality of cocoa beans in Central Highlands have not been published yet, nevertheless, this region has been reported to produce a very high yield of cocoa beans.

The physical properties of beans (size and mass) are factors that influence the quality of beans during the time of transportation and preservation (Bart-Plange and Baryeh, 2003). These factors have been investigated on soya beans (Deshpande *et al*.,1993), cumin beans (Singh and Goswani, 1996), bambara seeds (Baryeh, 2001), Malvaceae seeds (Rubina *et al*. 2016), *Ziziphus Nummularia* seeds (Nisar *et al*., 2021), *Linum Usitatissimum* seeds (Rizwan *et al*., 2021) and several other seeds.

This work compared fourteen dried fermented cocoa beans (Table 1) (TD1, TD2, TD3, TD5, TD6, TD7, TD8, TD9, TD10, TD11, TD12, TD13, TD14, and TD15) of Trinitario hybrids (Phạm, 2009; Nguyễn *et al*., 2011; Lâm, Nguyễn, Nguyễn *et al*., 2015). The ten out of the fourteen varieties were certified by the Ministry of Agriculture and Rural Development. Trinitario hybrids are a cross between the Criollo and Forastero groups. The Criollo groups are attributed with palatable flavour but are vulnerable to pathologies while Forastero groups have high-yield traits but the mediocre flavour (Lachenaud *et al*., 2007; Wood and Lass, 2008; Shri *et al*., 2009, Lâm, Vanlerberghe, Toan *et al*., 2015). All analysis was done using AOAC methods (AOAC Official Methods of Analysis, 1998). The data obtained in this work provided the basis for further breeding programmes of cocoa beans from southern Vietnam.

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Table 1. The origins of fourteen examined cocoa varieties (Lâm *et al*., 2015b)

Cocoa	Original	Origins	Sampling locations
TD1	BAL 209	Malaysia	TrangBom-ĐongNai
TD2	BAL 244	Malaysia	TrangBom-ĐongNai
TD3	BR 25	Malaysia	TrangBom-ĐongNai
TD5	KKM 22	Malaysia	TrangBom-ĐongNai
TD6	PCB 123	Malaysia	TrangBom-ĐongNai
TD7	PBC 154	Malaysia	TrangBom-ĐongNai
TD8	PBC 157	Malaysia	TrangBom-ĐongNai
TD9	PBC 159	Malaysia	TrangBom-ĐongNai
TD10	PBC 230	Malaysia	TrangBom-ĐongNai
TD11	PBC 236	Malaysia	TrangBom-ĐongNai
TD12	QH 1213	Malaysia	TrangBom-ĐongNai
TD13	QH 22	Malaysia	TrangBom-ĐongNai
TD14	QH 441	Malaysia	TrangBom-ĐongNai
TD15	UIT1	Malaysia	TrangBom-DongNai

2. Materials and methods

2.1 Materials

Fourteen cocoa varieties were sampled from different cocoa farms in the region of Trang Bom-Dong Nai between October-December, 2020.

2.2 Processing procedure of dehydrated seeds

Raw seeds were removed from the cocoa pod of fourteen varieties were individually fermented in wooden barrels 0.7×0.6×0.5 m (L×W×H) containing 20 kg cocoa seeds (6-7) days duration at an ambient temperature of Vietnam; the temperature could be around 45 -48°C during the fermentation of the mass). After fermentation, cocoa seeds were naturally dried under the sunlight for 7 -8 days, and the moisture content of the mass should be between 6% to 8% (wb).

2.3 Bean size

The length, width and thickness of cocoa beans were measured according to the Murray method (Murray, 1992). The shape and diameter of cocoa beans were measured by Micrometer screw gauge with 0.01mm accuracy (Stainless Steel Electronic LCD Digital Vernier Caliper Gauge Micrometer 0-6" Range) (Bart *et al*. 2003) (Figure 1). A total of 10 seeds randomly selected (Murray, 1992; Rubina *et al*, 2016) from 10 subsamples consisting of 100 seeds were measured and the mean values were analysed (Mohsenin, 1970; Shepherd and Bhardwaj, 1986; Dulta *et al*., 1988).

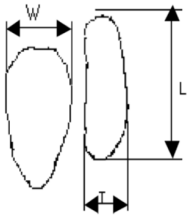

Figure 1. Cocoa bean size measurements (length, width and thickness)

2.4 Bean mass

The dehydrated cocoa beans were randomly selected and weighed on an electronic balance with 0.01g accuracy. The experiments were randomly repeated (5x100 random seeds) and mean values were calculated (Deshpande *et al*., 1993; Shepherd and Bhardwaj, 1986; Visvanathan *et al*., 1996; Aviara *et al*., 1999). The final values were divided by 100 to acquire the bean mass.

2.5 Cocoa bean processing method

Cocoa beans were processed followed by AOAC 935.52 (AOAC, 1998d). Crude cocoa beans collected at the cocoa centres and farms were analysed at Food Technology Engineering Lab (Ghent University). The bean shells were removed and the nibs were ground and refined (Hamilton Beach 80365 Custom Grind Hands-Free Coffee Grinder, Platinum). The refined cocoa nibs were analysed for their proximate composition.

2.6 Proximate analysis

2.6.1 Moisture content

Moisture content was examined by AOAC 925.40 (AOAC, 1998b). Samples were dried at 100°C to constant weight.

2.6.2 Ash content

Ash content was examined by AOAC 972.15 (AOAC, 1998e). Ash content was measured after constantly heating at 550°C in 16 hrs.

2.6.3 Crude protein content

Crude protein content was measured by AOAC 950.48 (AOAC, 1998c). The obtained value was multiply by 6.25.

2.6.4 Crude fat content

Crude fat content was measured by AOAC 948.22 (AOAC, 1998a). Fat content was extracted by petroleum and Soxtec System HT (Soxtec Extraction Unit 1043 and Service Unit 1046, Tecator, Hoganas, Sweden).

2.7 Statistical analysis

All the data were analysed by Statgraphics Statistical version 20.0 for analysis of variance (ANOVA) and Duncan's multiple range test. The least significant difference (LSD) was used to separate and compare the means and significance was accepted at 1% level (p<0.01). All treatments were designated in duplicate and mean values were reported. Values were expressed as percentage and mean±SD.

3. Results and discussion

3.1 Physical properties of cocoa bean (size and mass)

Data acquired from the Duncan test (Table 2) indicates that cocoa variety TD8 has the heaviest and largest seed (1.5 g of mass, 25.02 mm of length, 14.28 mm of width and 7.96 mm of thickness). In contrast, cocoa variety TD14 recorded the least values for all measured parameters (0.92 g of mass, 19.41 mm of length, 11.80 mm of width and 7.18 mm of thickness). These two varieties should therefore be taken into account by cocoa breeders when looking for cocoa varieties with good yields for large-scale cocoa cultivation. Compared to Ghanaian cocoa beans, TD8 has better bean quality for International exports since Ghanaian cocoa beans only weigh 1.31 g with other physical quality measurement values being smaller than those of TD8 (Bart-Plange and Baryeh, 2003).

For a broader view of cocoa bean size, Trần and Hồ (2011) reported one cocoa bean variety cultivated in Can Tho (Mekong Delta region) with similarly high values (19-25 mm of length, 12-13 mm of width, 7.2-99 mm of thickness) compared to Ghanaian cocoa bean size. This shows that some cocoa varieties cultivated in the southern of Vietnam adapt well to soil and climate and obtain better quality.

3.2 Proximate composition analysis

3.2.1 Moisture and ash content

The results showed the moisture content of the 14 cocoa varieties ranged from 5.64% to 6.99% (wb) at 0.01% (LSD) (Table 3) as compared to cocoa beans of Ghanaian origin which range between 5-24% (wb) (Bart-Plange and Baryeh, 2003). The large increment in moisture content between Vietnamese and Ghanaian cocoa beans demonstrates that the lower the moisture content, the more appropriate it is for storage and preservation since air-borne microbes and enzymatic reactions are reduced at low levels of moisture. The highest value of moisture content found in Vietnamese cocoa beans is only 6.99% (TD6) which is four times less than the highest moisture content reported for Ghanaian cocoa beans.

Table 3. Moisture and ash content of cocoa varieties from southern Vietnam

Varieties	Ash (%)	Moisture (%)
TD1	2.56±0.17^{de}	5.79±0.02^{ef}
TD2	2.61±0.01^{de}	6.09±0.10^{cdef}
TD3	3.05±0.03^{bc}	6.90±0.05^{ab}
TD5	3.05±0.02^{bc}	6.41±0.04^{bcd}
TD6	2.85±0.05^{bcd}	6.99±0.21^{a}
TD7	2.98±0.11^{bc}	6.23±0.04^{cde}
TD8	2.47±0.03e	5.85±0.04^{ef}
TD9	2.95±0.06^{bc}	6.47±0.28^{bc}
TD10	3.03±0.08^{bc}	5.91±0.24^{def}
TD11	2.95±0.09^{bc}	6.00±0.08^{cdef}
TD12	2.57±0.03^{de}	5.64±0.07^{f}
TD13	3.14±0.08^{b}	6.11±0.12^{cdef}
TD14	2.84±0.06^{cd}	6.20±0.05^{cde}
TD15	3.67±0.01^{a}	5.99±0.03^{cdef}

Values are expressed as mean±SD. Values with different superscripts within the column are significantly different (p<0.05).

Noticeably, the ash content of Vietnamese cocoa beans (2.5-3.7%) is considerably high compared to Ghanaian cocoa beans' ash content (2.3-3.5%) (Afoakwa *et al*., 2013). This proves that Vietnamese cocoa is rich in minerals since the ash property indicates mineral content. Further experiments will need to be conducted to further elaborate this.

3.2.2 Protein content

The total protein content of the fourteen examined

Table 2. Physical properties (bean size and mass) of cocoa varieties from southern Vietnam

Varieties	Mass (g)	Thickness (mm)	Length (mm)	Width (mm)
TD1	0.95±0.04^{fg}	7.42±1.16^{abc}	19.78±1.65^{gh}	12.68±0.89^{def}
TD2	1.00±0.03^{ef}	7.85±1.36^{a}	18.73±1.60^{i}	11.03±0.72^{g}
TD3	1.13±0.09^{c}	7.54±1.31^{ab}	21.02±1.66^{f}	12.79±0.74^{de}
TD5	1.05±0.03^{de}	6.77±1.04^{cd}	20.13±1.57^{gh}	12.48±0.69^{ef}
TD6	0.98±0.07^{efg}	7.1±1.17^{bcd}	21.98±1.45^{e}	12.90±0.92^{cde}
TD7	1.27±0.03^{b}	7.47±1.28^{ab}	25.30±1.74^{a}	13.13±0.83^{bcde}
TD8	1.50±0.04^{a}	7.96±1.21^{a}	25.02±2.23^{ab}	14.28±1.05^{a}
TD9	1.33±0.05^{b}	7.11±1.20^{bcd}	25.05±1.89^{a}	13.53±0.94^{abcd}
TD10	1.14±0.05^{c}	7.60±2.34^{ab}	24.19±1.51^{bc}	13.83±0.93^{abc}
TD11	1.13±0.01^{cd}	6.76±1.19^{d}	24.05±1.56^{c}	13.88±6.63^{ab}
TD12	0.96±0.03^{fg}	7.44±1.18^{ab}	20.31±1.52^{fg}	13.12±0.86^{bcde}
TD13	1.16±0.04^{c}	8.00±1.37^{a}	25.76±1.84^{a}	12.99±0.85^{bcde}
TD14	0.92±0.03^{g}	7.18±1.31^{bcd}	19.41±1.16^{hi}	11.80±0.68^{fg}
TD15	0.97±0.01^{efg}	7.69±1.16^{ab}	23.01±1.89^{d}	13.04±0.86^{bcde}

Values are expressed as mean±SD. Values with different superscripts within the column are significantly different (p<0.05).

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cocoa varieties ranged from 12.82% to 13.94% (WB) (Figure 2), this shows these values are not significantly different. At this point, the protein content of Vietnamese cocoa beans is slightly lower compared to other countries' protein content (Nigerian cocoa beans of 17.5% (Aremu *et al*., 1995), Ghanaian cocoa beans of 18.8% (Afoakwa *et al*., 2013).

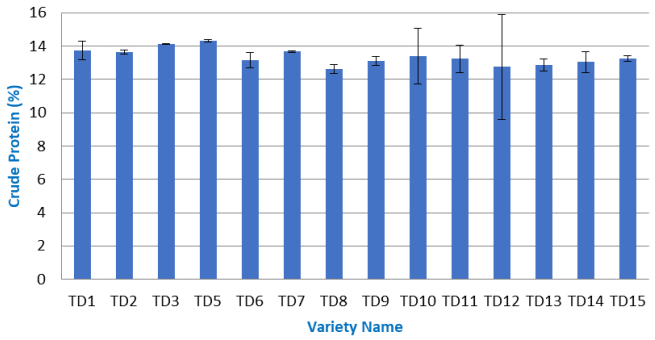

Figure 2. Total crude protein content of cocoa bean varieties from Southern Vietnam

3.2.3 Fat content

Based on the fat content values (Figure 3), the 14 cocoa varieties can be grouped into 3 major groups: group 1 has fat content under 30%, group 2 has a fat content between 30% and 50% and the last one, group 3 has fat content above 50%. Namely, group 1 consists of 2 varieties (TD8, TD15) and the lowest value of this group accounted for TD15 is 24.12%; group 2 has 5 varieties (TD3, TD6, TD7, TD9, TD10); group 3 includes 7 varieties (TD1, TD2, TD5, TD11, TD12, TD13, TD14) and the greatest value of this group was accounted for by TD12 (55.69%). The Vietnamese cocoa fat index is relatively comparable to Ghanaian cocoa fat quality which is approximately 50.40 - 55.21% (Afoakwa *et al*., 2013). Due to the fact that the yield of cocoa beans is considered to be a pivotal index of the cocoa purchase industry, thus these varieties of group 3 are potentially competitive in the International cocoa trade market.

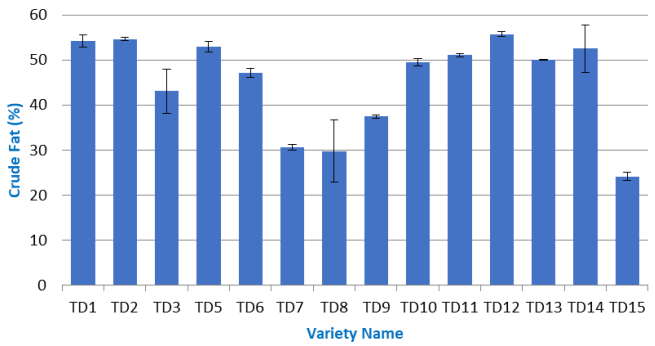

Figure 3. The fat content of 14 examined cocoa varieties from Southern Vietnam

TD1 of group 3 has been cultivated in some provinces of the south of Vietnam and yielded high-fat content according to the reports of Trần *et al*. (2010) and Trần and Hồ (2011). The fat content of 56% was reported in TD1 grown in Can Tho and Ben Tre (Mekong Delta region). Based on this fact, it might be concluded that the southern area of Vietnam indeed is well-suited for cocoa tree industrial cultivation and TD1 should primarily be noticed for selecting and breeding projects. The fat index in this research also reveals a paradoxical correlation that the largest bean size TD8 (group 1) resulted in greatly lower fat while the smallest bean size TD14 (group 3) attained a higher amount of fat (>50%). In contrast, Wood and Lass (2008) and Dand (1997) revealed that lower fat content was found in smaller bean sizes. This featuring trait should also be marked for cocoa cultivars.

4. Conclusion

The fourteen cocoa varieties were investigated for their physicochemical properties; bean size, mass and proximate compositions (protein, ash, fat, and moisture content). Noticeably, the TD12 bean variety recorded the highest fat content of 55.69%. Moreover, the TD8 bean varieties perform at best values which possess the largest size and heaviest mass. This proximate composition analysis should be marked for the cocoa cultivars project in Vietnam country. Further experiments with a focus on fibre content, polyphenol substances and antioxidants should be conducted. With the finite time and equipment, the elaboration on the correlation between Ash content and Minerals content could not carry out, thus future experiments should be investigated on this in order to supplement Vietnam cocoa bank data which can serve for breeding activities.

Conflict of interest

The authors declare no conflict of interest.

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