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CLASSIFICATION OF COPRA MEAL AND COPRA EXPELLERS BASED ON ETHER EXTRACT CONCENTRATION AND PREDICTION OF ENERGY CONCENTRATIONS IN COPRA BYPRODUCTS

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ABSTRACT

The objectives were to develop a classification standard for copra meal (CM) and copra expellers (CE) based on ether extract (EE) concentration and to develop prediction equations for EE and gross energy (GE) concentrations in copra byproducts. Data from 520 copra byproduct samples were used. Linear broken-line and quadratic models indicated breakpoints of 6.40 and 6.22% EE concentration to effectively distinguish the two copra byproducts, respectively. The EE was negatively correlated with moisture ($r = -0.611$, $P < 0.001$) and positively correlated with GE and organic matter (OM; $r > 0.56$, $P < 0.001$). The GE concentration in the copra byproducts showed a positive correlation with OM ($r = 0.524$, $P < 0.001$). The most suitable and simple prediction equations where the components were expressed in % (as-is basis) were EE = -77.0 + 0.976 × OM with $R^2 = 0.439$; GE, kcal/kg = 3,921 + 52.2 × EE with $R^2 = 0.324$. In conclusion, CM and CE can be distinguished by EE of 6.31%. Organic matter can be used to estimate EE and GE in copra byproducts.

Keywords: copra byproducts; ether extract; gross energy; nutrient composition; prediction equation.

INTRODUCTION

In many countries, a large quantity of feed ingredients for animals is imported from other countries, and the fluctuation in prices of conventional feed ingredients such as corn and soybean meal has led to the use of alternative feed ingredients (Son *et al.*, 2012; Kim *et al.*, 2015; Kwon and Kim, 2015). Copra or coconut byproducts are one of the alternative feed ingredients mostly produced in some areas of Africa and Southeast Asia such as the Philippines and Indonesia (Stein *et al.*, 2016). The price of the copra byproducts in the first quarter of 2015 was 184 dollars per a metric ton, which was less than half of the cost of soybean meal and a little less than of corn (Korea International Trade Association, 2016). Approximately 355,000 metric tons of copra byproducts were shipped into Korea in 2015, which accounted for approximately 4% of corn and soybean meal imported.

Depending on the different oil extraction procedures, the copra byproducts can be classified into mechanically extracted copra meal (copra expellers, CE; IFN 5-01-572; AAFCO, 2016) or solvent extracted copra meal (CM; IFN 5-01-573; AAFCO, 2016). However, there is no standard criterion for classifying the copra byproducts into CM and CE. Therefore, a simple and fast parameter is needed. The objectives of this study were to report chemical composition of copra byproducts to establish a standard for distinguishing CM and CE, and to develop the prediction equations for ether extract (EE) and gross energy (GE) concentrations in the copra byproducts.

MATERIALS AND METHODS

Plant sources: Data from 520 copra byproduct samples produced in the Philippines and Indonesia were used.

Chemical analysis: The copra byproducts were analyzed for moisture (method 930.15; AOAC, 2005) and ash (method 942.05; AOAC, 2005). Crude protein (CP) was determined using Dumas combustion method (Leco, St. Joseph, MI, USA), EE was analyzed by extracting crude fat with ether (method 920.39; AOAC, 2005), crude fiber (CF) was analyzed by the Ankom filter bag technique (method Ba 6a-05; AOCS, 2009), and Ca and P concentrations were analyzed by inductively coupled plasma spectroscopy (method 985.91; AOAC, 2005). Gross energy in the copra byproducts was determined using bomb calorimeter (Parr Instruments Co., Moline, IL, USA).

Statistical analysis: The homogeneity of EE concentrations in copra byproducts was tested using PROC UNIVARIATE of SAS (SAS Inst. Inc., Cary, NC, USA) and the data binning was also performed using a histogram.

A linear broken-line analysis (Robbins *et al.*, 2006) and a quadratic regression analysis were fitted with the EE concentration to separate copra byproducts into CM and CE. The PROC NLIN of SAS was used to find the breakpoint with the EE concentration as an independent variable and the frequency of occurrence as a dependent variable.

Correlation coefficients among the nutrient contents of the copra byproducts were determined using PROC CORR of SAS. Based on the correlation coefficients, regression analyses using PROC REG were performed with EE or GE concentration in the copra byproducts as dependent variables, and chemical compositions as independent variables using 388 samples with full data including GE. All equations were presented with root mean square error (RMSE), R^2, standard error (SE), and P-value. An α-level of statistical significance was set at 0.05.

RESULTS AND DISCUSSION

Histogram for ether extract concentration: The hypothesis of normality of the EE concentrations in the copra byproducts was rejected in the Shapiro-Wilk test ($P < 0.001$; data not shown). Based on the frequency of occurrence of EE concentrations in copra byproducts, two groups appeared to exist in copra byproducts (Figure 1).

A linear broken-line analysis indicated a breakpoint of 6.40% EE concentration in copra byproducts (SE = 0.20, $R^2 = 0.630$, $P < 0.001$; Figure 2). A quadratic model indicated another breakpoint of 6.22% EE concentration (SE = 0.10, $R^2 = 0.688$, $P < 0.001$; Figure 2). An EE concentration separating CM and CE would be between 6.22 and 6.40%.

Variation in chemical compositions: The nutrient contents in CM were slightly greater than that of CE except GE, EE, and CF concentrations (as-is basis; Tables 1, 2, and 3). Stein *et al.* (2015) reviewed nutritional values of copra, palm kernel, and rice byproducts and reported that dry matter, and CP contents were slightly lower in CE than in CM; and acid-hydrolyzed EE, and digestible and metabolizable energy concentrations were greater in CE compared with CM.

The moisture concentration in CM was 10.8% (Table 2) which was similar to the values (7.1 to 9.5%) in the literature (NRC, 1998; NRC, 2012; Jang and Kim, 2013; Sulabo *et al.*, 2013; Almaguer *et al.*, 2014) except for Sauvant *et al.* (2004; 13.2%). The moisture concentration in CE was 8.4% (Table 3) which was close to the range of values (8.5 to 11.3%) reported by Sauvant *et al.* (2004) and Son *et al.* (2012, 2013, 2014). The moisture concentrations in CE had relatively large variability (coefficient of variation, CV = 28.4%) which may be due to the storage condition and moisture determination procedure (Ahn *et al.*, 2014).

The GE concentration in the copra byproducts showed the relatively less variation than other chemical compositions (Tables 1, 2, and 3). The GE concentration in CM (4,068 kcal/kg; Table 2) was within the range of values (3,711 to 4,445 kcal/kg) reported by Sauvant *et al.* (2004), NRC (2012), Jang and Kim (2013), and Sulabo *et al.* (2013). The GE concentration in CE was 4,394 kcal/kg (Table 3) which was within the range of values (4,232 to 4,396 kcal/kg) reported by Sauvant *et al.* (2004), NRC (2012), and Son *et al.* (2012, 2013).

The CP concentration in the copra byproducts showed the least variation among the chemical compositions (Tables 1, 2, and 3). The CP concentration in CM was 21.3% (Table 2) which was within the range of values (20.3 to 22.0%) in the literature (Sauvant *et al.*, 2004; NRC, 2012; Jang and Kim, 2013; Sulabo *et al.*, 2013; Almaguer *et al.*, 2014). The CP concentration in CE (20.8%; Table 3) was also within the range of values (20.1 to 21.0%) in the literature (Sauvant *et al.*, 2004; Son *et al.*, 2012, 2013, 2014).

The EE concentrations were widely distributed, having the greatest CV value among other chemical compositions (Table 1). The CM contained 2.8% of EE (Table 2) which was within the range of values in the literature (NRC, 1998; Sauvant *et al.*, 2004; NRC, 2012; Jang and Kim, 2013; Sulabo *et al.*, 2013). The CE contained 9.3% of EE (Table 3) which was similar to the value reported by Sauvant *et al.* (2004), but 1.96% unit less than the values from the studies by Son *et al.* (2012, 2013, 2014).

The CF concentration in the copra byproducts showed a moderate variation (Table 1). The CF concentration in CM was 11.9% (Table 2) which was similar to the values (15.1 and 10.0%) in the literature (Sauvant *et al.*, 2004; Jang and Kim, 2013). The CF concentration in CE (12.2%; Table 3) was within the range of values (9.2 to 13.0%) reported by Sauvant *et al.* (2004) and Son *et al.* (2012, 2013, 2014).

The ash concentration in CM was 6.6% (Table 2) which was similar to the range of values (6.0 to 6.3%) in the literature (Sauvant *et al.*, 2004; Sulabo *et al.*, 2013; Almaguer *et al.*, 2014). The ash concentration in CE (6.1%; Table 3) was also close to the range of values (6.2 to 6.8%) reported by Sauvant *et al.* (2004) and Son *et al.* (2012, 2013, 2014).

Lastly, the Ca and P concentrations (Ca = 0.11 and P = 0.56%; Table 2) in CM were consistent with the range of values (Ca = 0.04 to 0.16% and P = 0.52 to 0.58%, respectively) reported by NRC (1998), Sauvant *et al.* (2004), NRC (2012), and Almaguer *et al.* (2014). The Ca and P concentrations (Ca = 0.10 and P = 0.55%; Table 3) in CE were within the range of values (Ca = 0.04 to 0.16% and P = 0.52 to 0.55%) reported by (Sauvant *et al.*, 2004; NRC, 2012; Son *et al.*, 2012, 2013, 2014).

Correlation coefficients among nutrient values: The EE concentration was negatively correlated with moisture, CP, and ash contents in the copra byproducts ($P < 0.001$; Table 4), and were positively correlated with GE and OM contents ($P < 0.001$). The correlation coefficient between EE and OM was greater than between EE and GE contents (r = 0.671 and 0.569, respectively).

The GE concentration in the copra byproducts had negative correlations with moisture and ash ($P < 0.01$; Table 4), resulting in the positive correlation with OM ($P < 0.001$). In the literature (Ewan, 1989; NRC, 2012), the GE concentration in feedstuffs was positively correlated with EE and CP and negatively correlated with ash. Park *et al.* (2012) also reported that GE concentrations in CM, palm kernel meal, cassava root, and the diets containing three feed ingredients were positively correlated with EE, CP, and fiber concentrations. In the present study, the most representing component for the energy contents was EE. The greatest correlation is likely due to the large contribution of EE to energy content and the large variation of EE content in the copra byproducts (CV = 68.7%; Table 1).

Prediction of ether extract and gross energy concentrations: The OM contents in the copra byproducts were able to well predict the EE concentrations ($P < 0.001$; equation 1 in Table 5). The analysis of EE in feed ingredients sometimes requires more efforts and expenses than determining moisture and ash. Therefore, the use of the equation 1 may be useful.

The GE concentrations (kcal/kg) were predicted by the EE, OM, or both ($P < 0.001$; Table 6). Coefficient of determination represents the accuracy of prediction, and these values in the present study were less than Park *et al.* (2012) that R^2 ranged from 0.69 to 0.93. Poorer accuracy may be partially explained by the fact that the GE contents in the copra byproducts in the present study did not vary extensively (Table 1) despite the large variation of EE.

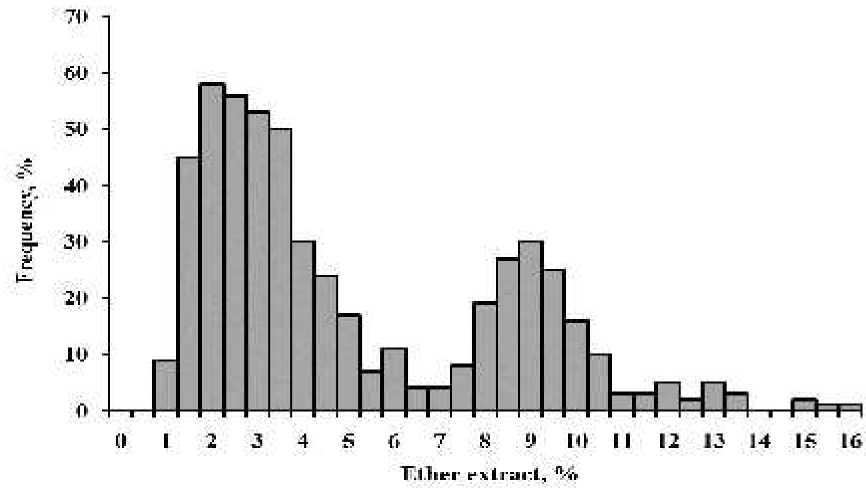

Figure 1. Frequency of occurrence of ether extract concentrations in copra byproducts (%, as-is basis; n = 528).

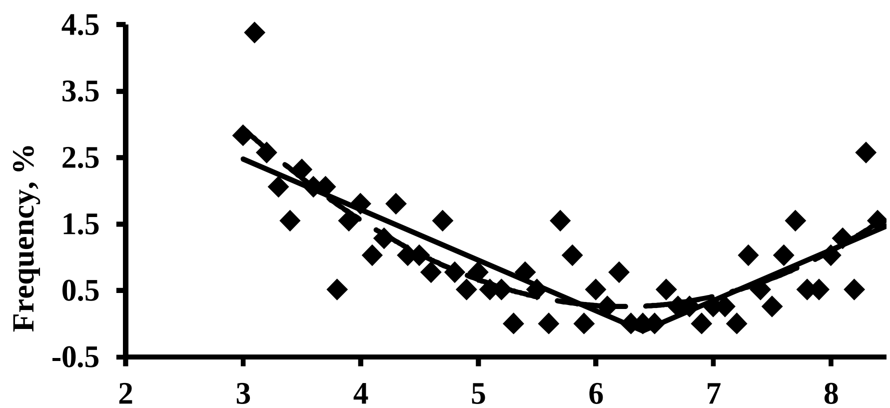

Figure 2. Linear broken-line and quadratic models for separating copra meal and copra expellers. A linear broken-line model indicated that a copra byproduct with ether extract (EE) concentration less than 6.40% (standard error = 0.20) was copra meal and that with EE greater than 6.40% was copra expellers based on the following equations: $Y = -0.11 + 0.75 \times (6.40 - X)$ where $X < 6.40$ and $Y = -0.11 + 0.77 \times (X - 6.40)$ where $X > 6.40$ ($R^2 = 0.630$, $P < 0.001$; represented by solid line). A quadratic model indicated that a breakpoint of EE concentration was 6.22% (standard error = 0.10) based on the following equation: $Y = 0.27 + 0.26 \times (X - 6.22)^2$ ($R^2 = 0.688$, $P < 0.001$; represented by dashed line). Data points represent 212 observations of EE concentrations in copra products (3.0% < EE < 8.5%, as-is basis).

Table 1. Chemical composition of copra byproducts (as-is basis).

Item, %	n	Average	SD	Maximum	Minimum	CV, %
Moisture	520	10.1	2.1	16.4	3.3	20.3
Gross energy, kcal/kg	388	4,159	290	6,143	2,761	7.0
Crude protein	520	21.2	1.0	24.4	18.7	4.5
Ether extract	528	4.8	3.3	15.8	0.6	68.7
Crude fiber	520	12.0	2.2	21.7	6.8	18.0
Ash	520	6.5	0.5	8.5	3.4	8.1
Ca	520	0.11	0.05	0.86	0.03	51.5
P	520	0.56	0.06	0.78	0.04	11.6

SD = standard deviation; CV = coefficient of variation.

Table 2. Chemical composition of solvent-extracted copra meal (ether extract < 6.31%; as-is basis).

Item, %	n	Average	SD	Maximum	Minimum	CV, %
Moisture	364	10.8	1.4	16.4	7.0	12.5
Gross energy, kcal/kg	280	4,068	257	6,143	2,761	6.3
Crude protein	364	21.3	0.9	24.2	18.7	4.4
Ether extract	364	2.8	1.2	6.1	0.6	44.1
Crude fiber	364	11.9	2.2	21.7	6.8	18.7
Ash	364	6.6	0.5	8.5	3.4	7.7
Ca	364	0.11	0.06	0.86	0.03	56.7
P	364	0.56	0.07	0.78	0.04	12.3

SD = standard deviation; CV = coefficient of variation.

Table 3. Chemical composition of copra expellers (ether extract > 6.31%; as-is basis).

Item, %	n	Average	SD	Maximum	Minimum	CV, %
Moisture	156	8.4	2.4	13.0	3.3	28.4
Gross energy, kcal/kg	108	4,394	235	5,016	3,886	5.4
Crude protein	156	20.8	0.9	24.4	18.7	4.4
Ether extract	164	9.3	1.7	15.8	6.5	18.2
Crude fiber	156	12.2	2.0	19.3	7.3	16.2
Ash	156	6.1	0.3	7.3	5.1	5.5
Ca	156	0.10	0.03	0.33	0.06	31.8
P	156	0.55	0.05	0.73	0.32	9.5

SD = standard deviation; CV = coefficient of variation.

Table 4. Correlation coefficients (r) among nutrient components in copra byproducts (as-is basis).

Item	CP	EE	CF	Ash	Ca	P	GE	OM
Moisture	-0.171^{***}	-0.611^{***}	0.065	0.113^{**}	0.139^{**}	-0.112^{*}	-0.518^{***}	-0.971^{***}
CP		-0.252^{***}	-0.236^{***}	0.330^{***}	0.054	0.267^{***}	-0.061	0.082
EE			0.0043	-0.391^{***}	-0.063	-0.059	0.569^{***}	0.671^{***}
CF				-0.233^{***}	0.053	-0.113^{**}	-0.023	-0.005
Ash					0.121^{**}	0.121^{**}	-0.162^{**}	-0.348^{***}
Ca						-0.078	-0.051	-0.160^{***}
P							0.014	0.077
GE								0.524^{***}

CP = crude protein; EE = ether extract; CF = crude fiber; GE = gross energy; OM = organic matter; $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; Each correlation coefficient represents 520 observations, except for GE in copra byproducts (388 observations).

Table 5. Regression equations for ether extract concentrations in copra byproducts (%, as-is basis; n = 388).

	Regression coefficient parameter			Statistical parameter		
Item	**Intercept**	**OM**	**CP**	**RMSE**	**R^2**	**P-value**
Equation 1	-77.0	0.976	-	2.38	0.439	< 0.001
SE	4.70	0.056	-	-	-	-
P-value	< 0.001	< 0.001	-	-	-	-
Equation 2	21.5	-	-0.796	3.08	0.056	< 0.001
SE	3.53	-	0.166	-	-	-
P-value	< 0.001	-	< 0.001	-	-	-
Equation 3	-59.0	1.01	-0.975	2.20	0.523	< 0.001
SE	4.85	0.052	0.119	-	-	-
P-value	< 0.001	< 0.001	< 0.001	-	-	-

OM = organic matter; CP = crude protein; RMSE = root mean square error; SE = standard error; All independent variables are in % (as-is basis).

Table 6. Regression equations for gross energy concentrations in copra byproducts (kcal/kg, as-is basis; n = 388).

	Regression coefficient parameter			Statistical parameter		
Item	**Intercept**	**EE**	**OM**	**RMSE**	**R^2**	**P-value**
Equation 4	3,921	52.2	-	239	0.324	< 0.001
SE	21.3	3.83	-	-	-	-
P-value	< 0.001	< 0.001	-	-	-	-
Equation 5	-1,744	-	70.6	248	0.274	< 0.001
SE	489	-	5.85	-	-	-
P-value	< 0.001	-	< 0.001	-	-	-
Equation 6	1,052	36.3	35.2	233	0.362	< 0.001
SE	598	4.98	7.33	-	-	-
P-value	0.079	< 0.001	< 0.001	-	-	-

EE = ether extract; OM = organic matter; RMSE = root mean square error; SE = standard error; All independent variables are in % (as-is basis).

Conclusion: We were able to classify copra meal as having less than 6.31% ether extract and copra expellers as having 6.31% ether extract or greater. Additionally, organic matter was a useful criterion to estimate gross energy as well as ether extract concentrations in copra byproducts.

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