PAPER

The demonstration of the invariant lipid-free composition and the mechanism varying energy and the main components of some mammal meats consisting of muscle and adipose tissue

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Abstract

Background: The assumption of an invariant fat-free or lipid-free composition is prerequisite for most methods of the estimation of body composition in mammals including human but has not been theoretically demonstrated. **Objective:** To demonstrate theoretically and practically the invariant lipid-free composition and to understand the mechanism varying the main components of muscle and adipose tissue which have intimate relationships to lipid accumulation or obesity in mammals. **Design:** Whether the combinations of correlations among energy and main components in the hypothetical lipid-ratio variation model (L-varied model), which reflects the invariant lipid-free composition, are consistent with those in the practical mammal meats? Do lipid-ratio variation (L-varied) equations based on L-varied model agree closely with the corresponding regression equations of energy and main components on lipid content in their meats? We designed to solve these questions and compare those results. **Results:** These combinations of their correlations between the theoretical model and practical meats stated above were consistent with each other. And the L-varied equations were consistent with the regression equations stated above. **Conclusion:** It is clarified that variation in energy reserves and main components, at least moisture, protein, and ash in them follow L-varied model. Consequently, for the first time we clearly demonstrated here that the assumption of an invariant lipid-free composition is valid in skeletal muscles and peripheral adipose tissues of some mammals.

Keywords: demonstration of invariant lipid-free composition; mammal muscle and adipose tissue; energy reserve; lipid-ratio variation model; regression equation

Introduction

To analyze in detail the variation in body composition through variation in lipid content intimately related to obese or lipid accumulation, we noted that the variation in composition of the adipose tissue to store lipid[1-3] and of the muscle to expend energy above all to oxidize lipid[4-7], which cause main variation in the body composition of mammal after chemical maturity.

It is well known that the percentages of protein and mineral matter or ash as well as moisture content which is about 73% of fat- free mass (FFM) commonly in whole body of mammals including human[8-10] are almost constant11 in them as well as cattle after chemical maturity[8]. This phenomenon on the invariant lipid-free composition also was confirmed here in the skeletal muscle and adipose tissue of various mammal meats including cattle ones. The assumption of an invariant fat-free or lipid-free composition is prerequisite for most methods of the estimation of body composition in mammals including human[1,10,11]. However, this assumption has not been theoretically demonstrated.

Whether the combinations of correlations among energy and main components in the hypothetical L-varied model, which varies the ratio of lipid to moisture, protein, carbohydrate, and ash and maintains a certain ratio among them, reflecting the invariant lipid-free composition, are consistent with those in the practical mammal meats? Does L-varied equations based on L-varied model agreed closely with regression equations of energy and main components on lipid content in their meats? Answering these questions would lead to the demonstration of the invariant fat-free or lipid-free composition at least in mammal muscle and adipose tissue. Furthermore, the results can lead to that demonstration in body composition in mammals including human. So we report as the affirmative results were obtained here. And also, as this L-varied model also designated only lipid as energy reserves, its reason was reported.

Materials and methods

As shown in Table 1, only raw foods were selected from the fifth revised Japanese standard tables of food composition[12]; total mammal meats (139 items) containing various skeletal muscles and/or subcutaneous and/or inter- and/or intra- muscular adipose tissues in various animals; wild boar, INOBUTA which is a cross between a pig and a boar, rabbit, horse, whale, deer, sheep, goat and various beef of Japanese, imported and veal and two types, pork of large and medium types. The series of groups consisting of parts of total mammal meats are the group of total beef meats (78 items), total swine meats (43 items), mammal meats except for total beef meats and total swine meats (14 items), beef meats with subcutaneous adipose tissue at 5 mm thick (beef lean and fat, 21items), beef meats that removed subcutaneous adipose tissue (subcutaneous fat- free beef meats, 21items), beef meats that removed subcutaneous and almost inter-muscular adipose tissue (beef lean meats, 21items). The other series of groups consisting of a part of total mammal meats are the group of muscles with subcutaneous adipose tissue at 5 mm thick (mammal lean and fat, 43 items), the group that removed subcutaneous and almost intramuscular adipose tissue from mammal lean and fat (mammal lean meats, 39 items), and the group consisting of subcutaneous and inter-muscular adipose tissues (mammal fat meats, 19 items). In addition to these groups, the group consisting of viscera such as heart, liver, kidney, stomach, small intestine, large intestine, rectum and uterus in pigs and cows (mammal viscera meats, 11 items).

Data in tables in the present paper were calculated based on the contents of main components of each food in the tables of food composition[12]. Contents of components per 100g of each food were expressed as follows; energy (kcal) calculated by FAO energy conversion coefficients, moisture (g), protein (g), lipid (g), carbohydrate (g), ash (g). The composition in meats examined here contains carbohydrate (g), content of which is not negligible compared to ash content in them.

In order to determine a correlation coefficient, the two-variation correlation of Pearson by statistical software SPSS11.5J (for Windows base model) was used for analyzing. Spearman rank correlation was also used in case of below 40 items. Significant probability was searched by the two-sided test about each correlation coefficient. Regression analysis was done by SPSS 11.5J.

The process and results of estimation on the theoretical correlation are shown as the following; contents of energy, moisture, protein, lipid, carbohydrate, and ash in each model is called as E, M, P, L, C, A, respectively. It is assumed that theoretical correlation coefficients among them are +1 or -1 if their correlations are perfect in the theoretical models. When L varies according to L- varied model, ML, PL, CL, AL, and EL are as the following; PL = (P/ (P+M+C+A)) (100-L), ML = (M/ (P+M+C+A)) (100-L), CL = (C/ (P+M+C+A)) (100-L), AL = (A/ (P+M+C+A)) (100-L), EL = 3.9PL + 9.02L + 4.11CL (The coefficients of the equation, 3.9, 902, and 4.11 indicate FAO energy conversion coefficients.) When the linear equation EL was solved, the coefficient of variable L, (5.08P+4.91C +9.02 (M+A)) / (P+M+C+A) in the simplified equation EL, is positive. Therefore the correlation coefficient of EL with L is +1. PL, ML, CL, and AL are dependent on the same variable (100-L). Thus the correlation coefficients of PL, ML, CL and AL with L are -1. The correlation coefficients among PL, ML, CL, and AL are +1. EL is positively depending on L while ML, PL, CL, and AL are negatively depending on L.

Therefore, the correlation coefficients of EL with ML, PL, CL and AL are – 1. When M varies according to moisture-ratio variation(M- varied) model, PM, LM, CM, and AM are as the following; PM = (P/ (P+L+C+A)) (100-M), LM = (L/ (P+L+C+A)) (100-M), CM = (C/(P+L+C+A)) (100-M), AM = (A/ (P+L+C+A)) (100-M), EM = 3.9PM + 9.02LM + 4.11CM. PM, LM, CM, AM, and EM are dependent on the variable (100-M). Thus each correlation coefficient of PM, LM, CM, AM, and EM with M is -1. The correlation coefficients among PM, LM, CM, AM, and EM are +1. Ash-ratio variation (A-varied) model can be solved similarly to M-varied model. When P varies according to protein-ratio variation (P-varied) model, MP, LP, CP, AP, and EP are as the following; LP = (L/ (M+L+C+A)) (100-P), MP = (M/ (M+L+C+A)) (100-P), CP = (C/ ((M+L+C+A)) (100-P), AP = (A/ (M+L+C+A)) (100-P), EP = 3.9P + 9.02LP + 4.11CP. EP = 9.11(L/ ((M+L+C+A)) (100-P) + 3.9P + 4.11(C/ (M+L+C+A)) (100-P). If 3.9P> 9.02(L/ (M+L+C+A)) P + 4.11(C/ ((M+L+C+A)) P, 3.9/5.12(M+A)>L+0.12C. Practically, this relationship is adaptable in groups of mammal muscle and fat meats except for a group of mammal fat meats (Table 2). Thus EP positively depends on P and the correlation coefficient of EP with P is+1. LP, MP, CP, and AP are dependent on the variables (100-P). Thus the correlation coefficients of LP, MP, CP and AP with P are -1. And the correlation coefficients among LP, MP, CP, and AP are +1 because they depend on the same variable (100-P). As the correlation coefficient of EP with P is +1 while those of MP, LP, CP, and AP with P are -1, therefore those of EP with MP, LP, CP and AP are – 1. Carbohydrate-variation (C-varied) model can be solved similarly to P-varied model.

In this paper we have regarded as significant correlation, which satisfied both conditions of more than |0.4| of correlation coefficient and less than 0.05 of significant probability. Although there may be the weak correlation that shows less than 0.05 of significant probability and below |0.4| of correlation coefficient in some food groups, this case is not mentioned as significant correlation in this paper, because correlations in the present paper are limited to what appeared externally, and do not contain the case of the correlation negated mutually and contain false correlation accidentally.

Results and Discussion

By removing lipid in any group of beef meats, consisting of different ratios of skeletal muscles and adipose tissues such as beef lean and fat, subcutaneous fat-free beef, beef lean, and total beef meats (Table 2), the coefficients of variation of moisture, protein, and ash are remarkably diminished together and the ratio among them excluding lipid approaches constancy just as suggested in fat-free body of cattle[8]. These phenomena did not appear by removing the other components of these beef meats (Table 2). These phenomena also were observed in swine and other mammal meats consisting of skeletal muscle and adipose tissue (Table 2).

Next, the theoretical correlations among energy and main components and the combinations in the other one-component ratio variation models as well as L-varied model stated above were compared with practical ones in various mammal meats to determine the most suitable model which can explain variation in these compositions.

Then the correlations among them were theoretically estimated in these models as stated in materials and methods. The results of estimation are shown in Table 3. When Spearman's rank correlation coefficients among energy and main components in various one-component-ratio variation models were calculated using the composition of real meats or total beef meats, their coefficients were near +1 or -1 similarly to those in the theoretical models and the combinations of their coefficients agreed perfectly with those in the theoretical models (Table 3). The theoretical correlations and their combinations in various models were compared with practical ones in real meats (Tables 3, 4). The frequency and degree of the agreement between the both and above all no existence of inverse relationship between positive and negative in the both indicating inverse relationship between increase and decrease in the related components, have been used here as a criterion for suitability of the best fitted model in comparison among these models.

The combinations of practical correlation coefficients among energy, moisture, protein, and ash in total beef meats, various beef meats with different amounts of adipose tissue, total swine meats, and the other mammal meats consisting of skeletal muscle and adipose tissue were in the best agreement with that of theoretical ones in L-varied model among these models because this model had no inverse relationship between positive and negative while the other models had at least four inverse ones (Tables 3, 4). These results are not in conflict with the previous reports that the negative correlations of fat with contents of ash and total nitrogen in the cattle muscle[13] and with moisture in the whole bodies of cattle[8] and goats[9] have been indicated. Therefore, it was suggested that in spite of the big range of variation owing to different ages, races, growth conditions, countries, and so on (Table 1), the composition of any group of beef and the other mammal meats consisting of the skeletal muscle and/or adipose tissue examined seems to be varied by the mechanism of L-varied model. The mechanism of L-varied model is essentially the same as the diluting effect of fattening on the concentrations of water, protein, and mineral matter or ash suggested in cattle[8] because a certain ratio of them was maintained and lipid content varied free from the ratio. Thus this similarity between the two suggests that variation in the composition of their skeletal muscle and adipose tissue results mainly from different degree of fattening in the original cattle and the other mammals before slaughter.

The L-varied equations indicating variation in main components of each group, based on L-varied model and summarized from materials and methods, are as the follows; moisture: ML = Km (100-X), protein: PL = Kp (100-X), carbohydrate: CL = Kc (100-X), ash: AL = Ka (100-X). X as independent variables shows lipid content in each meat. Coefficients, Km, Kp, Kc, and Ka show the ratio of each main component to all lipid-free components (Table 5). The arithmetic mean of all the groups consisting of both muscle and adipose tissue of mammals is Km: 0.76, Kp: 0.22, and Ka: 0.011, respectively. The coefficient of moisture is somewhat high and that of protein is somewhat low in the group of mammal fat meats. The Km at 0.76 is higher than widely quoted mean of 0.73 in FFM hydration in whole empty body because mammal muscle and adipose tissue contains no bone containing low moisture[10] and high ash contents[14]. Coefficient and constant obtained from these equations indicating variation in moisture, protein, and ash (Table 5) is very similar to those of regression equations of main components on lipid content (Table 6) because of small difference with below 2.5% between the two (Table 7). The correlations of practical contents of main components with the corresponding values obtained from lipid-ratio variation equation were high in those groups (Table 8). Therefore, it is clarified that variation in main components, at least moisture, protein, and ash in them follow L-varied model. For the first time we clarified here that the assumption of an invariant fat-free composition is valid in all the various mammal meats consisting of skeletal muscles and peripheral adipose tissues examined here as the ratio among main components excluding lipid in the lipid-free meats approaches constancy (Table 2) and variation in their composition is explained by L-varied model (Tables 3 to 8) as stated above.

Variation in composition of viscera tissues was scarcely consistent with any one-component ratio variation model as well as L-varied model because of little agreement with both the two (Tables 3 to 8). Thus it is assumed here that though whole-body FFM hydration seems to be equal to the sum of individual tissues divided[10], the diluting effect of lipid storage or fattening on the concentrations of moisture, protein, and ash in whole empty body may reflect mainly that of muscle and the peripheral adipose tissue because they are a large portion of the whole empty body[1,3,14,15] while viscera tissue and bone are small portions of that in human[14] and in cattle[3]. Therefore the diluting effect of fattening in whole cattle8 will be clearly explained by the application of L-varied model in future. Muscle and adipose tissue of mammals as a model system can be used in the same manner as whole empty body to understand the mechanism of variation in composition and fattening of mammals because these model systems have less variation factors and is simpler and easier, and less expensive than whole one.

As shown in Table 3, it is assumed that each one component-ratio variation model designates particular components as energy-storage components because of the positive and strong correlation between energy and particular energy-storage components. Lipid only as an energy-storage component in groups of the mammal skeletal muscle and/or adipose tissue is theoretically led from L-varied model (Tables 3, 4). Namely, the positive and strong correlation between energy and lipid and the negative correlations between energy and the other components such as moisture, protein, ash, and sometimes carbohydrate were practically observed in these groups as has been predicted by this model (Tables 3, 4). In these groups, the L-varied equation of energy dependent on lipid content based on L-varied model from results in materials and methods, is shown as EL＝3.9PL+9.02X+4.11CL =3.9Kp（100-X）+ 9.02X + 4.11Kc（100-X）(EL: amount of energy, the other signs are the same as stated above. And coefficients in the equation indicated FAO-energy conversion coefficients). The ratio of corresponding coefficients and constants in L-varied equation of energy to those of the regression equation of energy on lipid content, are near 1 and these were consistent with each other（Table 5, 6, 7）. The values obtained by equation EL correlated highly with practical energy quantity in each group of their meats (Table 8). Thus, from this validity of L-varied equation of energy, it was proved that the increase in energy leads to that in lipid in the composition of these meats. Therefore, if variation in their composition results mainly from different degree of fattening in a whole live body, the excess intake of energy rapidly stores surplus lipid, accompanying with the decrease in moisture, protein, ash, and sometimes carbohydrate and maintaining their ratios in mammal skeletal muscle and adipose tissues while the shortage energy intake shows the inverse relationship (Tables 3, 4).

It is widely known that dietary fat plays a specific role in the development of obesity[16]. It is suggested that high-fat diets promote fat stores or obesity because excessive carbohydrate and protein intakes promote the oxidation of them but excessive fat intake does not so[17]. However it remains unclear whether high-fat diets promotes fat stores because the different ratios of energy sources in diets with the same amount of energy shortage lead to similar decrease in weight and fat of obese person[18]. The body weight of an animal is maintained through a balance between food intake and energy expenditure[19]. The fact that L-varied model designate only lipid as energy reserves in mammal muscle and adipose tissue may result from the difference between fat and the other energy sources in the degree of metabolism[17]. However, the cause producing this difference in the metabolism may result from the in vivo mechanism of L-varied model which is maintaining constancy in lipid-free composition under excessive energy intake and no increased protein storage in mammal muscles. As suggested by Webster, J.D. et al [20], human body by excessive energy intake stores as 70-78% fat and 22-30% non-fat of the excess weight, the composition of which is similar to that of mammal fat meats (the mean content of lipid of 72.8%, co. of var.6%) in Table 2. Fat content in human body will approaches ultimately the theoretical limit or 68% fat indicated by Thomas E.L. et al1. However, there is perhaps an inherent limit of energy store as lipid in an individual of mammals including human because of the assumption that the constant ratio of energy stores as protein to total energy stored is set in an adult[21] and recent study that H3K9-specific demethylase, Jhdm2a regulates normal weight control in mice[22].

The one-component-ratio variation models proposed here can be widely applied to understand the mechanism varying and determining the composition and energy reserves of a whole or parts of the body in any animal and plant, providing a solid foundation of estimation methods for their composition.

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Table 1 The list of groups of mammal meats and the members

total mammal meats(139items)									
Japanese beef cattle chunk lean and fat	A			D			G		
Japanese beef cattle chunk without subcutaneous fat	A				E				
Japanese beef cattle chunk lean	A					F		H	
Japanese beef cattle chunk fat	A								I
Japanese beef cattle chunk loin lean and fat	A			D			G		
Japanese beef cattle chunk loin without subcutaneous fat	A				E				
Japanese beef cattle chunk lean	A					F		H	
Japanese beef cattle rib loin lean and fat	A			D			G		
Japanese beef cattle rib loin without subcutaneous fat	A				E				
Japanese beef cattle rib loin lean	A					F		H	
Japanese beef cattle rib loin fat	A								I
Japanese beef cattle rib Sirloin lean and fat	A			D			G		
Japanese beef cattle rib Sirloin without subcutaneous fat	A				E				
Japanese beef cattle rib Sirloin lean	A					F		H	
Japanese beef cattle Flank or short plate	A						G		
Japanese beef cattle inside round lean and fat	A			D			G		
Japanese beef cattle inside round without subcutaneous fat	A				E				
Japanese beef cattle inside round lean	A					F		H	
Japanese beef cattle inside round fat	A								I
Japanese beef cattle outside round lean and fat	A			D			G		
Japanese beef cattle inside round without subcutaneous fat	A				E				
Japanese beef cattle inside round lean	A					F		H	
Japanese beef cattle rump lean and fat	A			D			G		
Japanese beef cattle rump without subcutaneous fat	A				E				
Japanese beef cattle rump lean	A					F		H	
Japanese beef cattle fillet lean	A							H	
dairy fattened steer chunk lean and fat	A			D			G		
dairy fattened steer chunk without subcutaneous fat	A				E				
dairy fattened steer chunk lean	A					F		H	
dairy fattened steer chunk fat	A								I
dairy fattened steer chunk loin lean and fat	A			D			G		
dairy fattened steer chunk loin without subcutaneous fat	A				E				
dairy fattened steer chunk loin lean	A					F		H	
dairy fattened steer rib loin lean and fat	A			D			G		
dairy fattened steer rib loin without subcutaneous fat	A				E				
dairy fattened steer rib loin lean	A					F		H	
dairy fattened steer rib loin fat	A								I
dairy fattened steer SIr loin lean and fat	A			D			G		
dairy fattened steer Sir loin without subcutaneous fat	A				E				
dairy fattened steer Sir loin lean	A					F		H	
dairy fattened steer flank or short plate lean and fat	A						G		
dairy fattened steer inside round lean and fat	A			D			G		
dairy fattened steer inside round without subcutaneous fat	A				E				
dairy fattened steer inside round lean	A					F		H	
dairy fattened steer inside round fat	A								I
dairy fattened steer outside round lean and fat	A			D			G		
dairy fattened steer outside round without subcutaneous fat	A				E				
dairy fattened steer outside round lean	A					F		H	
dairy fattened steer rump lean and fat	A			D			G		
dairy fattened steer rump without subcutaneous fat	A				E				
dairy fattened steer rump lean	A					F		H	
dairy fattened steer fillet lean	A							H	
Imported beef chunk lean and fat	A			D			G		
Imported beef chunk without subcutaneous fat	A				E				
Imported beef chunk lean	A					F		H	
Imported beef chunk fat	A								I
Imported beef chunk loin lean and fat	A			D			G		
Imported beef chunk loin without subcutaneous fat	A				E				
Imported beef chunk loin lean	A					F		H	
Imported beef rib loin lean and fat	A			D			G		
Imported beef chunk loin without subcutaneous fat	A				E				
Imported beef rib loin lean	A					F		H	
Imported beef rib loin fat	A								I
Imported beef Sir loin lean and fat	A			D			G		
Imported beef Sir loin without subcutaneous fat	A				E				
Imported beef Sir loin lean	A					F		H	
Imported beef flank and short plate lean and fat	A						G		
Imported beef inside round lean and fat	A			D			G		
Imported beef inside round without subcutaneous fat	A				E				
Imported beef inside round lean	A					F		H	
Imported beef inside round fat	A								I
Imported beef outside round lean and fat	A			D			G		
Imported beef outside round without subcutaneous fat	A				E				
Imported beef outside round lean	A					F		H	
Imported beef rump lean and fat	A			D			G		
Imported beef rump without subcutaneous fat	A				E				
Imported beef rump lean	A					F		H	
Imported beef fillet lean	A							H	
Veal rib loin without subcutaneous fat									
Veal flank or short plate without subcutaneous fat									
Veal inside round without subcutaneous fat									
swine large type breed picnic shoulder lean and fat		B					G		
swine large type breed picnic shoulder without subcutaneous fat		B							
swine large type breed picnic shoulder lean		B						H	
swine large type breed picnic shoulder fat		B							I
swine large type breed Boston butt lean and fat		B					G		
swine large type breed Boston butt without subcutaneous fat		B							
swine large type breed Boston butt lean		B						H	
swine large type breed Boston butt fat		B							I
swine large type breed loin lean and fat		B					G		
swine large type breed loin without subcutaneous fat		B							
swine large type breed loin lean		B						H	
swine large type breed loin fat		B							I
swine large type breed belly lean and fat		B					G		
swine large type breed inside ham lean and fat		B					G		
swine large type breed inside ham without subcutaneous fat		B							
swine large type breed inside ham lean		B						H	
swine large type breed inside ham fat		B							I
swine large type breed outside ham lean and fat		B					G		
swine large type breed outside ham without subcutaneous fat		B							
swine large type breed outside ham lean		B						H	
swine large type breed outside ham fat		B							I
swine large type breed fillet lean		B						H	
swine medium type breed picnic shoulder lean and fat		B					G		
swine medium type breed picnic shoulder without subcutaneous fat		B							
swine medium type breed picnic shoulder lean		B						H	
swine medium type breed picnic shoulder fat		B							I
swine medium type breed Boston butt lean and fat		B					G		
swine medium type breed Boston butt without subcutaneous fat		B							
swine medium type breed Boston butt lean		B							
swine medium type breed Boston butt fat		B							I
swine medium type breed loin lean and fat		B					G		
swine medium type breed loin without subcutaneous fat		B							
swine medium type breed loin lean		B						H	
swine medium type breed loin fat		B							I
swine medium type breed belly lean and fat		B					G		
swine medium type breed inside ham lean and fat		B					G		
swine medium type breed inside ham without subcutaneous fat		B							
swine medium type breed inside ham lean		B							
swine medium type breed inside ham fat		B							I
swine medium type breed outside ham lean and fat		B					G		
swine medium type breed outside ham without subcutaneous fat		B							
swine medium type breed outside ham lean		B						H	
swine medium type breed outside ham fat		B							I
swine medium type breed fillet lean								H	
wild boar lean and fat			C				G		
INOBUTA lean and fat			C				G		
rabbit lean			C					H	
horse meat lean			C					H	
whale meat lean			C					H	
whale ventral groove meat			C						
whale blubber			C						
deer meat lean			C					H	
sheep mutton loin lean and fat			C				G		
sheep mutton leg lean and fat			C				G		
sheep lamb shoulder lean and fat			C				G		
sheep lamb loin lean and fat			C				G		
sheep lamb leg lean and fat			C				G		
goat meat lean			C					H	

mammal viscera meats (11items)
cattle offals heart
cattle offals liver
cattle offals kidney
cattle offals omasum
cattle offals small intestine
cattle offals large intestine
cattle offals rectum
swine offals heart
swine offals liver
swine offals kidney
swine offals uterus

Kinds of groups inadition of groups of total mammal meats and mammal viscera meats;
A:total beef meats (78items)
B:total swine meats (43items)
C:mammal meats except for beef and swine (14iten
D:beef lean and fat (21items)
E:subcutaneous fat-free beef meats (21items)
F:beef lean meats (21items)
G:mammal lean and fat (43items)
H:mammal lean meats (39items)
I:mammal fat meats (19items)

Table 2 Composition of main components and each one component-free composition in various groups of mammal meats

Groups		composition of original foods (%)						lipid-free mass (LFM)(%)				moisture-free mass (MFM)(%)				protein-free mass (PFM)(%)			
		energy	moisture	protein	lipid	carbohydrate	ash	moisture	protein	carbohydrate	ash	protein	lipid	carbohydrate	ash	moisture	lipid	carbohydrate	ash
Total beef meats	average	291	57.3	16.7	24.9	0.3	0.8	76.7	21.8	0.4	1.1	46.4	50.4	0.9	2.3	70.0	28.6	0.4	1.0
	co. of va	58	27	30	84	56	29	2.6	8.4	49.2	6.7	46.8	46.1	67.0	46.3	30.1	75.3	57.9	31.9
	red. rate							0.1	0.3	0.9	0.2	1.5	0.6	1.2	1.6	1.1	0.9	1.0	1.1
Beef lean and fat	average	278	58.5	17.1	23.3	0.3	0.8	76.2	22.3	0.5	1.1	43.4	53.6	0.9	2.1	70.8	27.7	0.4	1.0
	co. of va	31	14	14	46	42	15	0.9	2.9	37.7	5.5	29.1	25.1	50.1	29.3	16.2	42.2	43.6	17.5
	red. rate							0.1	0.2	0.9	0.4	2.1	0.6	1.2	1.9	1.2	0.9	1.0	1.1
Subcutaneous fat-free beef meats	average	250	61.0	17.9	19.8	0.4	0.9	76.1	22.4	0.5	1.1	48.7	47.9	1.0	2.4	74.6	23.9	0.5	1.1
	co. of va	35	13	14	54	43	15	1.0	2.9	38.0	5.6	29.1	31.7	51.8	30.1	15.7	50.2	44.9	17.4
	red. rate							0.1	0.2	0.9	0.4	2.1	0.6	1.2	2.0	1.2	0.9	1.0	1.2
Beef lean meats	average	178	67.7	20.2	10.8	0.4	1.0	75.8	22.6	0.5	1.1	64.8	30.7	1.3	3.1	84.9	13.3	0.5	1.2
	co. of va	35	9	9	71	43	9	1.0	2.9	40.6	4.0	22.2	50.3	49.3	22.7	10.4	67.9	44.3	11.1
	red. rate							0.1	0.3	0.9	0.4	2.6	0.7	1.1	2.4	1.2	1.0	1.0	1.2
Total swine meats	average	304	56.1	16.4	26.5	0.1	0.9	76.8	21.9	0.1	1.2	49.1	48.0	0.4	2.5	69.2	29.6	0.1	1.1
	co. of va	71	36	39	101	88	36	2.1	7.2	87.2	7.1	55.4	60.1	90.6	53.6	39.4	93.7	88.5	39.2
	red. rate							0.1	0.2	1.0	0.2	1.4	0.6	1.0	1.5	1.1	0.9	1.0	1.1
Mammal meats except for beaf and swine	average	227	63.1	18.9	16.9	0.2	0.9	75.5	23.2	0.3	1.0	58.9	37.7	0.7	2.7	78.6	20.1	0.3	1.1
	co. of va	65	23	17	105	68	24	3.9	12.3	71.4	6.4	39.9	66.2	81.9	44.0	24.8	98.3	69.5	26.0
	red. rate							0.2	0.7	1.0	0.3	2.3	0.6	1.2	1.8	1.1	0.9	1.0	1.1
Total mammal meats	average	283	58.0	17.0	23.9	0.2	0.8	76.6	22.0	0.3	1.1	49.7	47.2	0.7	2.5	71.3	27.3	0.3	1.0
	co. of va	65	29	32	95	75.0	31	2.6	8.6	71.9	8.4	49.1	54.9	82.2	49.2	32.4	86.2	76.2	33.8
	red. rate							0.1	0.3	1.0	0.3	1.5	0.6	1.1	1.6	1.1	0.9	1.0	1.1
Mammal lean and fat	average	275	58.8	17.2	22.9	0.3	0.8	76.3	22.3	0.3	1.1	43.9	53.3	0.6	2.2	71.3	27.4	0.3	1.0
	co. of va	31	14	14	45	63	16	1.1	3.4	60.6	6.6	27.8	24.3	68.6	28.7	15.8	41.9	64.4	17.8
	red. rate							0.1	0.2	1.0	0.4	2.0	0.5	1.1	1.8	1.2	0.9	1.0	1.1
Mammal lean meats	average	154	69.9	20.8	8.0	0.3	1.0	75.9	22.6	0.4	1.1	71.4	24.0	1.1	3.5	88.4	9.9	0.4	1.3
	co. of va	36	8	8	84	67	10	1.2	3.6	57.4	5.9	19.9	62.4	58.6	21.3	9.0	81.6	57.9	11.4
	red. rate							0.2	0.4	0.9	0.6	2.5	0.7	1.0	2.2	1.2	1.0	1.0	1.2
Mammal fat meats	average	676	21.9	5.1	72.7	0.03	0.3	80.2	18.6	0.1	1.1	6.6	93.0	0.0	0.4	23.1	76.6	0.0	0.3
	co. of va	7	22	24	8	2280	33	2.4	10.3	242.7	15.5	28.0	2.1	250.8	30.6	23.1	7.1	248.3	27.1
	red. rate							0.1	0.4	1.0	0.5	1.2	0.3	1.0	1.2	1.0	0.9	1.0	1.0
Mammal viscera meats	average	127	76.4	14.6	7.5	0.6	0.9	82.7	15.7	0.6	1.0	65.0	28.9	2.1	4.0	89.5	8.6	0.7	1.1
	co. of va	44	8	25	94	211	43	5.9	22.1	210.6	39.9	27.9	70.0	208.4	32.1	8.3	89.8	211.5	46.7
	red. rate							0.7	0.9	1.0	0.9	1.1	0.7	1.0	0.8	1.0	1.0	1.0	1.1
Mean**	average	248.8	61.1	18.0	19.7	0.3	0.9	76.2	22.4	0.4	1.1	52.9	43.6	0.8	2.6	75.5	23.1	0.4	1.1
	co. of va	47.3	19.1	19.7	75.9	60.7	20.5	1.8	5.8	57.1	6.2	35.5	46.8	66.7	36.1	21.5	70.8	60.8	22.9
	red. rate							0.1	0.3	0.9	0.3	2.0	0.6	1.1	1.9	1.1	0.9	1.0	1.1

The reduction rate(red. rate); the coefficient of variation of each main component-free mass/the coefficient of variation of each main component in the compositon of original foods
Carbohydrate-free mass (CFM)% and ash-free mass (AFM)% were omitted because the red. rate of main components in all the food groups were about 1.0.
co. of var.; coefficient of variation(%)=standard deviation/mean x 100
Mean**; the arismetic mean among the other groups excep for mammal fat and viscera meats

Table 3 The theoretical correlation coefficients (theoretical) among energy and main components calculated theoretically based on one component- ratio variation model and Spearman's correlation coefficients among them in total beef meats (total beef) modified with variation in the content of each main component

kinds of one-component ratio variation models		correlation between														
		Energy					Moisture				Protein			Lipid		Carbo-hydrate
		Moisture	Protein	Lipid	Carbo-hydrate	Ash	Protein	Lipid	Carbo-hydrate	Ash	Lipid	Carbo-hydrate	Ash	Carbo-hydrate	Ash	Ash
M-varied model	thoretical	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1
	total beef	-1.00	1.00	1.00	0.99	1.00	-1.00	-1.00	-0.99	-1.00	1.00	0.99	1.00	0.99	1.00	0.99
L-varied model	thoretical	-1	-1	1	-1	-1	1	-1	1	1	-1	1	1	-1	-1	1
	total beef	-1.00	-1.00	1.00	-0.98	-1.00	1.00	-1.00	0.98	1.00	-1.00	0.98	1.00	-0.98	-1.00	0.98
P-varied model	thoretical	-1	1	-1	-1	-1	-1	1	1	1	-1	-1	-1	1	1	1
	total beef	-1.00	1.00	-1.00	-0.97	-1.00	-1.00	1.00	0.97	1.00	-1.00	-0.97	-1.00	0.97	1.00	0.97
C-varied model	thoretical	-1	-1	-1	1	-1	1	1	-1	1	1	-1	1	-1	1	-1
	total beef	-1.00	-1.00	-1.00	1.00	-0.99	1.00	1.00	-1.00	0.99	1.00	-1.00	0.99	-1.00	0.99	-0.99
A-varied model	thoretical	1	1	1	1	-1	1	1	1	-1	1	1	-1	1	-1	-1
	total beef	1.00	1.00	1.00	0.97	-1.00	1.00	1.00	0.97	-1.00	1.00	0.97	-1.00	0.97	-1.00	-0.97

When the one-component-ratio variation models in which the content of one main component was independently varied at 5g-intervals in range of 5-95gFW, maintainig the ratio among the other main components of real meats or total beef meats were used, Spearman's rank correlation coefficients of them were shown as total beef.
(significant probability in all the correlation coefficients<0.01)

Table 4 Correlation coefficients among energy and main components in various groups of mammal meats

Groups		correlation between								
		Energy					Moisture			
		Moisture	Protein	Lipid	Carbohydrat	Ash	Protein	Lipid	Carbohydrat	Ash
Total beef meats	r	-1.000	-0.990	1.000	-0.657	-0.983	0.986	-0.999	0.644	0.980
	probability	6.94E-118	1.02E-66	1.01E-137	6.37E-11	2.19E-57	1.59E-60	1.71E-103	2.00E-10	6.17E-55
Beef lean and fat	rs	-0.995	-0.936	0.997	-0.284	-0.854	0.908	-0.989	0.264	0.842
	probability	1.00E-06	1.00E-06	1.00E-06	2.12E-01	1.00E-06	1.00E-06	1.00E-06	2.47E-01	1.74E-06
Subcutaneous fat-free beef meats	rs	-0.997	-0.890	0.994	-0.397	-0.844	0.871	-0.989	0.369	0.831
	probability	1.00E-06	1.00E-06	1.00E-06	7.47E-02	1.52E-06	1.00E-06	1.00E-06	9.98E-02	3.14E-06
Beef lean meats	rs	-0.980	-0.798	0.987	-0.257	-0.757	0.718	-0.955	0.192	0.703
	probability	1.00E-06	1.48E-05	1.00E-06	2.61E-01	7.04E-05	2.50E-04	1.00E-06	4.04E-01	3.81E-04
Total swine meats	r	-1.000	-0.994	1.000	-0.676	-0.994	0.991	-0.999	0.666	0.993
	probability	9.73E-70	1.08E-40	8.85E-80	6.37E-07	1.56E-40	1.52E-37	9.86E-62	1.10E-06	6.23E-40
Mammal meats except for beaf and swine	rs	-0.968	-0.828	0.988	-0.002	-0.908	0.782	-0.954	0.059	0.928
	probability	1.00E-06	2.57E-04	1.00E-06	9.94E-01	7.26E-06	9.43E-04	1.00E-06	8.40E-01	1.72E-06
Total mammal meats	r	-0.999	-0.986	1.000	-0.460	-0.975	0.980	-0.999	0.454	0.974
	probability	3.41E-207	1.23E-109	2.77E-241	1.11E-08	1.61E-92	1.52E-98	3.05E-179	1.95E-08	7.31E-90
Mammal lean and fat	r	-0.998	-0.959	1.000	-0.168	-0.907	0.943	-0.996	0.140	0.899
	probability	2.46E-53	4.18E-24	3.21E-63	2.82E-01	5.19E-17	3.85E-21	2.63E-45	3.72E-01	2.49E-16
Mammal lean meats	rs	-0.977	-0.684	0.989	0.250	-0.628	0.573	-0.950	-0.311	0.583
	probability	1.00E-06	1.59E-06	1.00E-06	1.25E-01	1.85E-05	1.38E-04	1.00E-06	5.39E-02	9.86E-05
Mammal fat meats	rs	-0.995	-0.836	0.997	-0.415	-0.878	0.802	-0.990	0.368	0.878
	probability	1.00E-06	8.41E-06	1.00E-06	7.75E-02	1.00E-06	3.59E-05	1.00E-06	1.21E-01	1.00E-06
Mammal viscera meats	rs	-0.747	-0.127	0.856	0.209	0.056	-0.392	-0.441	-0.620	-0.566
	probability	8.23E-03	7.09E-01	7.61E-04	5.38E-01	8.71E-01	2.33E-01	1.75E-01	4.18E-02	6.94E-02

Groups		correlations between					
		Protein			Lipid		Carbohydrat
		Lipid	Carbohydrat	Ash	Carbohydrat	Ash	Ash
Total beef meats	r	-0.992	0.696	0.981	-0.664	-0.984	0.697
	probability	1.08E-70	1.61E-12	5.57E-56	3.40E-11	2.72E-58	1.39E-12
Beef lean and fat	rs	-0.948	0.376	0.873	-0.299	-0.862	0.527
	probability	1.00E-06	9.33E-02	1.00E-06	1.87E-01	1.00E-06	1.41E-02
Subcutaneous fat-free beef meats	rs	-0.922	0.607	0.897	-0.435	-0.865	0.546
	probability	1.00E-06	3.53E-03	1.00E-06	4.85E-02	1.00E-06	1.04E-02
Beef lean meats	rs	-0.856	0.568	0.845	-0.308	-0.806	0.491
	probability	1.00E-06	7.20E-03	1.47E-06	1.75E-01	1.01E-05	2.37E-02
Total swine meats	r	-0.995	0.721	0.988	-0.682	-0.994	0.672
	probability	8.93E-43	5.03E-08	1.42E-34	4.65E-07	1.91E-40	8.09E-07
Mammal meats except for beaf and swine	rs	-0.849	0.302	0.767	-0.024	-0.910	0.081
	probability	1.24E-04	2.94E-01	1.38E-03	9.35E-01	6.34E-06	7.84E-01
Total mammal meats	r	-0.989	0.504	0.966	-0.474	-0.976	0.441
	probability	1.05E-115	2.63E-10	3.80E-82	3.73E-09	3.49E-92	5.38E-08
Mammal lean and fat	r	-0.967	0.260	0.889	-0.184	-0.909	0.171
	probability	4.46E-26	9.19E-02	1.71E-15	2.37E-01	3.71E-17	2.72E-01
Mammal lean meats	rs	-0.758	0.021	0.703	0.229	-0.668	-0.193
	probability	1.00E-06	8.97E-01	1.00E-06	1.61E-01	3.31E-06	2.40E-01
Mammal fat meats	rs	-0.851	0.284	0.745	-0.427	-0.856	0.310
	probability	3.96E-06	2.39E-01	2.54E-04	6.85E-02	3.02E-06	1.97E-01
Mammal viscera meats	rs	-0.465	0.905	0.815	-0.164	-0.190	0.770
	probability	1.50E-01	1.30E-04	2.24E-03	6.29E-01	5.75E-01	5.61E-03

r; Pearson's correlation coefficient, rs; Spearman's rank correlation coefficient
probability; significant probability of correlation coefficients

Table 5 The mean coefficient (K) of L-varied equations of energy and each main components in various groups of mammal meats

Groups		Moisture (Km)	Protein (Kp)	Carbohydrate (Kc)	Ash(Ka)	Energy coefficient	Energy contstant
Total beef meats	coefficient*	0.77	0.22	0.0042	0.011	8.152	86.845
	S.D.	0.02	0.02	0.0020	0.001	0.076	7.615
Beef lean and fat	coefficient*	0.76	0.22	0.0045	0.011	8.133	88.690
	S.D.	0.01	0.01	0.0017	0.001	0.028	2.769
Subcutaneous fat-free beef meats	coefficient*	0.76	0.22	0.0045	0.011	8.128	89.172
	S.D.	0.01	0.01	0.0017	0.001	0.029	2.896
Beef lean meats	coefficient*	0.76	0.23	0.0046	0.011	8.119	90.150
	S.D.	0.01	0.01	0.0019	0.000	0.030	3.037
Total swine meats	coefficient*	0.77	0.22	0.0013	0.012	8.160	85.963
	S.D.	0.02	0.02	0.0011	0.001	0.065	6.472
Mammal meats except for beaf and swine	coefficient*	0.75	0.23	0.0028	0.010	8.102	91.776
	S.D.	0.03	0.03	0.0020	0.001	0.116	11.615
Total mammal meats	coefficient*	0.77	0.22	0.0030	0.011	8.149	87.058
	S.D.	0.02	0.02	0.0022	0.001	0.078	7.759
Mammal lean and fat	coefficient*	0.76	0.22	0.0033	0.011	8.138	88.181
	S.D.	0.01	0.01	0.0020	0.001	0.033	3.309
Mammal lean meats	coefficient*	0.76	0.23	0.0036	0.011	8.123	89.740
	S.D.	0.01	0.01	0.0021	0.001	0.035	3.529
Mammal fat meats	coefficient*	0.80	0.19	0.0008	0.011	8.292	72.756
	S.D.	0.02	0.02	0.0019	0.002	0.073	7.298
Mammal viscera meats	coefficient*	0.83	0.16	0.0062	0.010	8.382	63.794
	S.D.	0.05	0.03	0.0131	0.004	0.178	17.809
Mean**	coefficient	0.76	0.22	0.0035	0.011	8.134	88.619
	S.D.	0.00	0.00	0.0011	0.000	0.018	1.827

Coefficient* is indicates the mean coefficient (K) of each component in L-varied equation in each group. L-varied equautions of energy and each main components and Km, Kp, Kc, and Ka are the same as the results in the present paper. Mean**; the same as the foot note in Table 2. S.D.; standard deviation

Table 6 Regression equations of energy and main components on lipid in various groups of mammal meats

Groups		Moisture	Protein	Carbohydrate	Ash	Energy
Total beef meats	coefficient	-0.741	-0.242	-0.006	-0.011	8.052
	constant	75.720	22.701	0.480	1.097	90.510
Beef lean and fat	coefficient	-0.764	-0.220	N	-0.011	8.141
	constant	76.230	22.210	N	1.102	88.492
Subcutaneous fat-free beef meats	coefficient	-0.759	-0.223	-0.007	-0.011	8.124
	constant	76.040	22.365	0.498	1.097	89.268
Beef lean meats	coefficient	-0.767	-0.214	N	-0.011	8.152
	constant	75.920	22.489	N	1.086	89.771
Total swine meats	coefficient	-0.746	-0.240	-0.003	-0.011	8.073
	constant	75.859	22.799	0.185	1.157	89.675
Mammal meats except for beaf and	coefficient	-0.814	-0.174	N	-0.011	8.338
	constant	76.867	21.871	N	1.038	86.230
Total mammal meats	coefficient	-0.748	-0.237	-0.004	-0.011	8.081
	constant	75.918	22.636	0.339	1.108	89.675
Mammal lean and fat	coefficient	-0.762	-0.224	N	-0.012	8.135
	constant	76.280	22.298	N	1.111	88.267
Mammal lean meats	coefficient	-0.769	-0.221	N	-0.012	8.167
	constant	75.986	22.584	N	1.118	89.367
Mammal fat meats	coefficient	-0.807	-0.176	N	-0.012	8.315
	constant	80.573	17.850	N	1.201	71.189
Mammal viscera meats	coefficient	-0.648	N	N	N	7.694
	constant	81.235	N	N	N	69.313
Mean**	coefficient	-0.763	-0.222	-	-0.011	8.140
	constant	76.091	22.439	-	1.102	89.028

When significant probability of coefficient is over 0.05, the regression equations are not valid, indicating N in the columns. Mean**; the same as the foot note in Table 2.

Table 7 The similarity in the corresponding coefficients and constants of energy and main compo
between L-varied equations and the corresponding regression equations in various mammal mea

Groups		Moisture	Protein	Carbohydrate	Ash	Energy
Total beef meats	coefficient	1.03	0.90	0.69	0.98	1.01
	constant	1.01	0.96	0.87	0.99	0.96
Beef lean and fat	coefficient	1.00	1.01	N	0.99	1.00
	constant	1.00	1.00	N	0.99	1.00
Subcutaneous fat-free beef meats	coefficient	1.00	1.00	0.65	0.99	1.00
	constant	1.00	1.00	0.91	0.99	1.00
Beef lean meats	coefficient	0.99	1.06	N	0.99	1.00
	constant	1.00	1.01	N	1.00	1.00
Total swine meats	coefficient	1.03	0.91	0.44	1.07	1.01
	constant	1.01	0.96	0.71	1.02	0.96
Mammal meats except for beaf and swine	coefficient	0.93	1.34	N	0.92	0.97
	constant	0.98	1.06	N	0.98	1.06
Total mammal meats	coefficient	1.02	0.93	0.76	1.01	1.01
	constant	1.01	0.97	0.90	1.00	0.97
Mammal lean and fat	coefficient	1.00	0.99	N	0.91	1.00
	constant	1.00	1.00	N	0.98	1.00
Mammal lean meats	coefficient	0.99	1.02	N	0.93	0.99
	constant	1.00	1.00	N	0.99	1.00
Mammal fat meats	coefficient	0.99	1.06	N	0.96	1.00
	constant	1.00	1.04	N	0.96	1.02
Mammal viscera meats	coefficient	1.28	N	N	N	1.09
	constant	1.02	N	N	N	0.92
mean 1		1.02	1.02	0.63	0.98	1.01
S.D.		0.09	0.12	0.14	0.05	0.03
mean 2		1.00	1.00	0.85	0.99	0.99
S.D.		0.01	0.03	0.09	0.02	0.04
mean 3		1.00	1.02	0.63	0.98	1.00
S.D.		0.03	0.13	0.14	0.05	0.01
mean 4		1.00	1.00	0.85	0.99	1.00
S.D.		0.01	0.03	0.09	0.01	0.03
mean 5		1.01	1.01	0.74	0.98	1.00
S.D.		0.06	0.09	0.16	0.04	0.03

Mean indicates the arithmetic mean of the ratio of coefficients and constants of energy and each main componet in L-varied equation to those of regression equation in each group of mammal meats

N; no significant equation

mean 1; mean among all the coefficients

mean 2; mean among all all the constants

mean 3; mean among coefficients without groups of fat and viscera meats

mean 4: mean among constants without groups of fat and viscera meats

mean 5; mean among all the coefficients and contants

S.D.; standard deviation

Table 8 Correlations between the practical contents and the values calculated from L-varied equations in composition of various groups of mammal meats

Groups		Moisture	Protein	Carbohydrate	Ash	Energy
Total beef meats	r	0.999	0.992	0.664	0.984	1.000
	significant	***	***	***	***	***
Beef lean and fat	rs	0.989	0.948	0.299	0.862	0.997
	significant	***	***	N	***	***
Subcutaneous fat-free beef meats	rs	0.989	0.922	0.435	0.865	0.994
	significant	***	***	*	***	***
Beef lean meats	rs	0.955	0.856	0.308	0.806	0.987
	significant	***	***	N	***	***
Total swine meats	r	0.984	0.995	0.682	0.994	1.000
	significant	***	***	***	***	***
Mammal meats except for beaf and swine	rs	0.954	0.849	0.024	0.910	0.988
	significant	***	***	N	***	***
Total mammal meats	r	0.999	0.989	0.467	0.976	1.000
	significant	***	***	***	***	***
Mammal lean and fat	r	0.996	0.967	0.184	0.909	1.000
	significant	***	***	N	***	***
Mammal lean meats	rs	0.950	0.758	-0.229	0.668	0.989
	significant	***	***	N	***	***
Mammal fat meats	rs	0.990	0.851	0.427	0.856	0.997
	significant	***	***	N	***	***
Mammal viscera meats	rs	0.441	0.465	0.164	0.190	0.856
	significant	N	N	N	N	***

r; Pearson's correlation coefficient, rs: Spearman's correlation coefficient
significant; significant level, *; between below5% and above 1%, ***; below 0.1%