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Review Article
Nutritional quality and properties of protein and lipid in processed meat products – a perspective

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Abstract: Protein Efficiency Ratio (PER) is the most widely used method for determining protein quality. The studies involved a few category of products as raw materials namely poultry products, beef burger products, fish and fish products, soy products and palm kernel cake in animal diet preparation were compiled to compare the data. Data from the proximate analysis showed that protein content in soy protein isolate (SPI) was the highest (95.00%) followed by meat such as mackerel fish (89.09%) and beef (88.60%). Results from feed consumption and total protein consumed showed that the rats fed with mechanically deboned poultry meat (MDPM) products (excluding broiler back) consumed more feed, ranging from 469.2g to 422.3g during the study while the lowest total feed consumed (157.7g) was recorded in the rat fed a diet of fermented palm kernel cake (fPKC). The total protein consumed by rat for diets of fish and fish products such as canned sardine was 62.36g, mackerel 61.76g and anchovy at 58.91g, followed by MDPM products. *Tempeh* (14.72g) and fPKC diet (16.3g) were among the lowest total protein consumed by the rats. Growth and PER data for rats fed a diet of canned sardine, anchovy and mackerel, as well as mechanically deboned turkey meat (MDTM) and mechanically deboned chicken meat (MDCM) had higher mean body weight (154.80g, 145.20g, 144.81g, 148.7g and 142.5g respectively) compared to rats fed with plant protein diet such as SPI, *tempeh* and PKC (34.79g, 16.34g and 16.60g respectively) whereas rats fed diets containing fPKC had a mean body weight loss of 24.4g. MDPM showed higher PER value (ranging from 3.01 to 3.34) compared to hamburger group, pure beef and fish group. *Tempeh* and SPI had lower PER of 1.02 and 1.52 respectively while the lowest PER of 0.50 and -1.50 were shown in PKC and fPKC. The highest digestibility was shown in mackerel (96.99%), followed by canned sardine (96.88%), *tempeh* (91.41%), meat (90.79%) and pure beef burger (90.04%) while digestibility of PKC and fPKC were much lower (45.70% and 22.60%). Lipid profile of rats fed with palm based fat beef burger showed that palm fat(PF) and red PF did not affect the total cholestrol concentration but resulted in higher high density lipoprotein (HDL)-cholesterol concentration in their blood serum. In summary, the utilization of PF and red PF in beef burger increased the HDL-cholesterol and has no effect on the concentration of total cholesterol in rat blood serum.

Keywords: nutritional quality, processed meat, lipid, protein

Introduction

Meat, fish, poultry and legumes are important sources of protein for many communities around the world. These protein sources provide many of the essential amino acids for building body proteins and are often refered to as high quality protein. Vegetable protein, such as soybean foods are also high in protein and have been shown to offer specific health benefits. They may possess anticarcinogenic properties related to the unique benefits of soy isoflavones, phytochemicals which exert biological effects in humans and other animals (HHS and USDA, 2005). There have been limited studies on protein nutritional quality conducted by researchers in Asia and the Pacific region. A few studies related to Malaysian main sources of protein in food were reviewed to compare the quality of proteins as evaluated by the rat bioassay study of Protein Efficiency Ratio (PER) measurement.

Fat utilization, especially saturated fat, is still considerd to be surplus. According to the nutritional guidelines and other health watch groups, dietary fat should provide between 15 and 30 % of total calories, and that saturated fats should be limited to between 0 and 10% of calorie intake and cholestrol intake below 300 mg/day (Carrol, 1998; Chizzolini *et al.*, 1999). In general, research to reduce and replace animal fats with vegetables oils in various type of meat products has gotten much attention in the meat manufacturing industry (Wan Rosli *et al.,* 2007). Reductions in fat and cholestrol intakes are thought to be imporatnt measures to prevent obesity and hypercholesterolemia, conditions that are considered predisposed to various chronic diseases of the circulatory system (Chizzolini *et al.,* 1999). Palm oil has a number of advantages over animal fat and oil. For one, it improves the nutritional value of end product. Substituting animal fats, which are high in cholestrol and saturated fat with palm fats rich in natural carotenes and vitamin E is an alternative for meat products. According to Babji (2006) palm oil and especially palm fat, can be used as a fat source in the production of comminuted meat product without

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Table 1. PER, digestibility, amino acids score and PDCAAS for some selected proteins

Protein	PER	Digestibility	AAS (%)	PDCAAS
Egg	3.8	98	121	118
Cow's milk	3.1	95	127	121
Beef	2.9	98	94	92
Soy	2.1	95	96	91
Wheat	1.5	91	47	42

Source: Schaafsma (2000)

adversely affecting on the sensory attributes rating of bologna.

Protein quality evaluation

Protein quality evaluation was aimed at determining the capacity of food protein sources and diets to satisfy the metabolic demand for amino acids and nitrogen (WHO, 2007). Thus, any measures of the overall quality of dietary protein, if correctly determined, should predict the overall efficiency of protein utilization. According to Schaafsma (2000) and Reeds *et al*. (2000), there are a number of methods utilized to determine protein quality. Generally, these methods include the Chemical Score or Acid Amino Score (AAS), Protein Efficiency Ratio (PER), Biological Value (BV) or Protein Digestability Corrected Amino Acid Score (PDCAAS). Table 1 shows values of PER, digestibility, amino acids score and PDCAAS for some selected proteins.

Egg was the first to be assigned a chemical score as it was considered to be nutritionally complete. The essential amino acid in other sources is compared to the quantity of that amino acid in egg protein (Brody, 1999). Protein Efficiency Ratio (PER) is based on the weight gain of a growing rat divided by its intake of a particular food protein during the test period. The PER is then calculated by dividing the weight gain by the protein intake (Mitchell *et al.,* 1989). Joint FAO/WHO Expert Consultation (2007) reported that Biological Value (BV) measures the amount of nitrogen retained divided by nitrogen absorbed. The amino acid profile is assumed to determine the effectiveness with which absorbed dietary nitrogen can be utilized. If a given protein provides all the essential amino acids in the correct proportions and is readily absorbed, the BV score will approach protein's maximal potential quality (Hoffman and Flavo 2004). The newest measure of protein quality is the PDCAAS. The method has been considered to be a simple and scientifically sound approach for routine assessment of dietary protein quality for humans (Hoffman and Flavo, 2004).

Protein efficiency ratio (PER) studies

Since 1919, the PER method is the most widely used procedure for determining protein quality in many countries because it was believed to be the best predictor of clinical tests (Boutrif, 1991). It is also the official method in Canada and United States (Schaafsma, 2000). It is a simple assay that measures the efficiency of utilization of protein for growth as influenced by food intake (Hackler, 1984).

Rat diet preparation

In Malaysia, PER studies are limited to only a few institutions, such as UKM and recently, MARDI. Studies that used materials and food products that can be obtained locally were compiled to compare the data. The studies involved a few category of products as a raw materials in diet preparation for rat study, namely poultry products (MacNeil *et al.,* 1978; Babji *et al.,* 1980), beef burger products (Babji and Selvakumari, 1989), fish and fish products (Babji *et al.,* 2007), soy products (Nur Azlina *et al.,* 2007) and palm kernel cake (Marini *et al.,* 2007). The ingredients or processed raw materials that were used in rat diet formulation were shown in Table 2.

Results from feed consumption and total protein consumed differ and vary significantly among the few selected studies on rat bioassay carried out in Malaysia. Sample preparation of rat diets vary even though using procedures for PER as outlined by AOAC 1975 [a,b], 1984 [c,e], 2000 [d, f], due to varied chemical composition and the biological nature of raw materials. Protein, fat, moisture and carbohydrate contents vary widely, making standardization of 10% protein, 8% fat and other specified components tedious to prepare. The processes of drying, defatting and mixing of diets also contributed to the final protein quality. These factors will affect the total feed consumed including the protein uptake by the rats. It is obvious that meat proteins are well accepted while plant proteins are not so easily consumed by the rats.

From the results shown in Table 3, most of the

Table 2. Ingredients or processes of raw material in rat diet formulation of various products

Products	Ingredient / Process
Skinless broiler neck (SN) [a]	Byproduct of poultry processing
Skinless broiler neck & back (SNBK) [a]	Byproduct of poultry processing
Broiler back (BK) [a]	Byproduct of poultry processing
Chicken (MDCM) [b]	Frozen mechanically deboned broiler neck and back meat with skin (equal portions of backs and necks) [b]
Cooked fowl meat (CMDFM) [b]	Frozen mechanically deboned cooked fowl meat [b]
Turkey (MDTM) [b]	Frozen mechanically deboned turkey frame meat without skin [b]
Pure beef [c]	100% beef [c]
Beef-soy mixture (70:30) [c]	70% beef : 30% hydrated textured protein [c]
Beef burger (Angus) [c]	Beef, soy protein, salt, spices, food conditioner, flavour and colour [c]
Beef burger (Fika) [c]	Beef, spices, soy protein, sugar and salt [c]
Beef burger (Ramly) [c]	Beef, beef fat, soy protein, onion, salt, sugar, spices, food conditioner, flavour and MSG [c]
Beef burger (Thrifty) [c]	Beef, potato, onion, starch, bread crumbs, eggs, spices and colour [c]
Anchovy [d]	-
Mackerel [d]	Boiled at 100ºC prior to diet preparation [d]
Canned sardine [d]	Had undergone ultra heat temperature for sterilization purpose [d]
Soy protein isolate (SPI) [e]	-
Meat [e]	-
Tempeh [e]	Fermented soy bean; *tempeh* had been fermented for 72 hours [e]
Milk casein [e]	Lactic acid casein diet (reduced content of sulfur that contain amino acid, methionine) [e]
Palm kernel cake (PKC) [f]	Solid residue left behind after the extraction of oil from the kernel of oil palm fruits [f]
Fermented palm kernel cake (fPKC) [f]	Fermented sterile PKC substrate [f]

Sources : [a] MacNeil *et al.,* 1978, [b] Babji *et al.,* 1980, [c] Babji and Selvakumari 1989, [d] Babji *et al.,* 2007, [e] Nur Azlina *et al.,* 2007, [f] Marini *et al.,* 200

Table 3. Comparison of total feed consumed and total protein consumed in various products

Products	Total feed consumed (g/rat/28 days) (g)	Total protein consumed (g/rat/28 days) (g)
Skinless broiler neck (SN) [a]	451.20	40.60
Skinless broiler neck & back (SNBK) [a]	431.90	38.90
Broiler back (BK) [a]	373.40	33.60
Chicken (MDCM) [b]	469.20	47.40
Cooked fowl meat (CMDFM) [b]	422.30	41.60
Turkey (MDTM) [b]	455.90	45.50
Pure beef [c]	328.10	33.04
70:30 [c]	320.70	32.26
Beef burger (Angus) [c]	268.10	27.02
Beef burger (Fika) [c]	273.00	28.66
Beef burger (Ramly) [c]	285.20	29.82
Beef burger (Thrifty) [c]	293.20	29.82
Anchovy [d]	373.80	58.91
Mackerel [d]	405.26	61.76
Canned sardine [d]	393.94	62.36
Soy protein isolate (SPI) [e]	236.29	22.94
Meat [e]	356.98	34.38
Tempeh [e]	200.37	14.72
Milk casein [e]	250.19	25.94
Palm kernel cake (PKC) [f]	284.30	30.40
Fermented palm kernel cake (fPKC) [f]	157.70	16.30

Source: [a] MacNeil *et al.,* 1978, [b] Babji *et al.,* 1980, [c] Babji and Selvakumari 1989, [d] Babji *et al.,* 2007, [e] Nur Azlina *et al.,* 2007, [f] Marini *et al.,* 2007

rats fed with mechanically deboned poultry meat (MDPM) products (excluding broiler back) consumed more feed, ranging from 469.2g to 422.3g during the study. The lowest total feed consumed (157.7g) was recorded in the rat fed a diet of fermented palm kernel cake (fPKC). The low consumption of fPKC diet might be due to variations in flavour and appearance compared to regular rat feed (Marini *et al.,* 2007). Babji *et al.* (2007) reported that the total protein consumed of diet with fish and fish products like canned sardine was at 62.36g, mackerel at 61.76g and anchovy at 58.91g, followed by MDPM products. *Tempeh* (14.72g) and fPKC (16.3g) were among the lowest total protein consumed by the rats in two of the studies. Both diets, *tempeh* and fPKC, were derived from plant proteins.

Protein efficency ratio (PER) assay

Total weight gained and PER data for rats fed different diets are shown in Table 4. The rats fed diets of canned sardine, anchovy and mackerel, as well as mechanically deboned turkey meat and mechanically deboned chicken meat (MDTM and MDCM) had higher mean body weight (154.80g, 145.20g, 144.81g, 148.7g and 142.5g respectively) compared to other treatments. All rats fed with plant protein diets such as SPI, *tempeh* and PKC were reported to have low body weight gained (34.79g, 16.34g and 16.60g respectively) whereas rats fed diets containing fPKC had a mean body weight loss of 24.4g.

MDPM showed higher PER value (ranging from 3.01 to 3.34) compared to other groups of diets. Among the beef burger group, pure beef was the highest PER value of 2.98, followed by 70:30 (2.94) and Thrifty (2.67). Lower PER value of other burgers

Table 4. Comparison of growth (body weight gained) and PER fed with various products

Products	Total weight gained (g)	PER
Skinless broiler neck (SN) [a]	139.50	-
Skinless broiler neck & back (SNBK) [a]	125.70	-
Broiler back (BK) [a]	82.90	-
Casein (R) [a]	111.70	-
Chicken (MDCM) [b]	142.50	3.01
Cooked fowl meat (CMDFM) [b]	129.10	3.11
Turkey (MDTM) [b]	148.70	3.34
Casein (R) [b]	137.10	3.22
Pure beef [c]	99.00	2.98
70:30 [c]	95.00	2.94
Beef burger (Angus) [c]	61.00	2.26
Beef burger (Fika) [c]	69.00	2.38
Beef burger (Ramly) [c]	74.00	2.45
Beef burger (Thrifty) [c]	80.00	2.67
Casein (R) [c]	60.00	2.30
Anchovy [d]	145.20	2.46
Mackerel [d]	144.81	2.34
Canned sardine [d]	154.80	2.48
Casein (R) [d]	145.99	2.31
Soy protein isolate (SPI) [e]	34.79	1.52
Meat [e]	102.73	2.99
Tempeh [e]	16.34	1.02
Milk casein [e]	50.07	1.93
Sodium caseinate (R) [e]	57.30	2.41
Palm kernel cake (PKC) [f]	16.60	0.50
Fermented palm kernel cake (fPKC) [f]	-24.40	-1.50
Casein (R) [f]	92.70	2.70

Source: [a] MacNeil *et al.,* 1978, [b] Babji *et al.,* 1980, [c] Babji and Selvakumari 1989, [d] Babji *et al.,* 2007, [e] Nur Azlina *et al.,* 2007, [f] Marini *et al.,* 2007

could be due to addition of nonmeat components in the formulation which can alter the protein quality of the product (Babji and Selvakumari, 1989). Brody (1999) has also stated that the PER value of fish is 3.55, which showed that results obtained from the fish group consisting of canned sardine, anchovy and mackerel were much lower (2.48, 2.46 and 2.34 respectively). Babji *et al.* (2007) concluded that the protein quality was affected by various processes in diet preparation such as sterilizing, heating and boiling.

PKC and fPKC had the lowest PER of 0.50 and -1.50. Several causes such as high fiber content, the presence of toxic substances and undesirable odours and taste were postulated to be the factors related to the poor PER value (Marini *et al.,* 2007).

Tempeh and SPI are soy products. Both products had PER of 1.02 and 1.52 respectively. Accoding to Hoffman and Flavo (2004), soy is a complete protein with a high concentration of branched chain amino acids. However, PER scale may have rated soy product as low protein quality. When PDCAAS scale is used, soy protein was reported to be equivalent to animal protein with a score of 1.0, the highest possible rating. Boutrif (1991) reported that PER is now recognized to overestimate the value of some animal proteins for human growth while it underestimates the value of some vegetable proteins for that purpose. Since most of these methods used a rat assay, measurement of amino acid requirements was done in rat rather than the human. This is particularly misleading, since the rat appears to have

Table 5. *In vivo* and *in vitro* measurement of protein digestibility of various products

Products	*In vivo* digestibility (%)	*In vitro* digestibility (%)
Skinless broiler neck (SN) [a]	-	-
Skinless broiler neck & back (SNBK) [a]	-	-
Broiler back (BK) [a]	-	-
Chicken (MDCM) [b]	89.92	89.33
Cooked fowl meat (CMDFM) [b]	90.11	90.00
Turkey (MDTM) [b]	87.04	88.65
Pure beef [c]	90.04	85.57
70:30 [c]	87.91	84.82
Beef burger (Angus) [c]	85.50	82.94
Beef burger (Fika) [c]	86.18	83.31
Beef burger (Ramly) [c]	85.50	82.56
Beef burger (Thrifty) [c]	85.91	83.69
Anchovy [d]	91.29	-
Mackerel [d]	96.99	-
Canned sardine [d]	96.88	-
Soy protein isolate (SPI) [e]	89.52	-
Meat [e]	90.79	-
Tempeh [e]	91.41	-
Milk casein [e]	91.34	-
Palm kernel cake (PKC) [f]	45.70	-
Fermented palm kernel cake (fPKC) [f]	22.60	-

Source: [a] MacNeil *et al.,* 1978, [b] Babji *et al.,* 1980, [c] Babji and Selvakumari 1989, [d] Babji *et al.,* 2007, [e] Nur Azlina *et al.,* 2007, [f] Marini *et al.,* 2007

a much higher requirement for sulphur amino acids than does the human (Boutrif, 1991). Therefore, a protein might be more than adequate for maintenance purposes, might be an excellent source of protein in a mixed feeding situation in humans but receive a low PER value, since it was not found to promote growth (Hackler, 1984).

The role of dietary proteins is to provide substrates required for the synthesis of body proteins and other metabolically important nitrogen-containing compounds. For this reason, the content of nutritionally indispensable amino acids in a protein or mixture of food proteins is usually a primary determinant of protein nutritional quality (Young and Pellet, 1984).

Currently, information on protein nutritional quality of studies in Malaysia is based almost entirely on the use of the rat PER assay procedure. In 1989, Codex Committee on Vegetable Proteins (CCVP), while elaborating general guidelines for the utilization of vegetable protein products in foods, felt the need for a suitable indicator to express protein quality. It pointed out that PER might not be the most suitable means for protein quality evaluation. A protein quality study of PER that requires a 4-week rat feeding trial is also impractical, as well as expensive (Bodwell *et al.,* 1989). A common criticism of most rat bioassay procedures is that it is difficult to measure the potential complementary and supplementary effects of two or more proteins in a mixed feeding situation, which is how humans consumed their food. Further, the PER procedure may penalize the high-quality proteins as well as the low-quality proteins when they are fed as a single source of protein at a specified level (Hackler, 1984).

However, until additional human data on rates of growth, maintenance needs and the manner of consuming a variety of foods containing various protein sources at each meal are obtained, or any advantages reported for other procedures such as a multidose assay, these simple rat assay procedures are recommended for quality control of protein-containing foods. This is due to economic and labour-saving considerations along with the reproducibility of the data within and between laboratories (Hackler, 1984).

In vivo and *in vitro* digestability

Table 5 shows the *in vivo* apparent digestibility and *in vitro* protein digestibility of various raw materials commonly used in food and feed products. The highest digestibility was shown in mackerel (96.99%), followed by canned sardine (96.88%). The digestibility for *tempeh* was 91.41 which was higher than meat (90.79) or pure beef burger (90.04). All hamburgers also had lower digestibility value compared to pure burger due to the presence of soy protein (Babji and Selvakumari, 1989). Even though *tempeh* is a form of soya, it was processed via fermentation without undergoing thermal processing. According to Rackis *et al.* (1975), 80% of the trypsin inhibitor activity is destroyed via heating, enabling higher digestibility value for most soy products. Digestibility of PKC and fPKC were much lower compared to other products, 45.70 and 22.60 due to the fibre, odour and taste factors (Marini *et al.,* 2007).

From the studies conducted for *in vitro* digestibility, all MDPM sources were found to have approximately equal values of *in vivo* and *in vitro* digestibility. Babji *et al.* (1980) reported there was no significant differences between the *in vivo* and *in vitro* digestibility values. Study by Babji & Selvakumari (1989) also showed the same trend, for *in vivo* or *in vitro* digestibility, the highest shown in pure beef burger (90.04, 85.57), followed by the 70:30 mixture at 87.91 *(in vivo)* and 84.82 *(in vitro)*.

Lipid profile of rat

Four beef burger formulations were prepared, each containing 15% fat from either beef fat (control, C), palm fat (PF), red PF or a blend of PF and red PF at a ratio of 1:1 at 15% fat. A rat assay was carried out to determine the lipid profile. At the end of the experimental period and after 12 hr of fasting, rats were weighed, deeply sedated with barbiturate. Blood samples were obtained from the abdominal aorta and centrifuged at 1500 rpm for 15 min. Sera were stored at -80° C before analysis. Serum was analysed for total, low density lipoprotein cholestrol (LDL-C), high density lipoprotein-cholesterol (HDL-C) and triglycerides (TG) using- Cabas Mira Chemical Analyser (Roche) (Wan Rosli *et al.,* 2007). Research protocols were approved by the Wistar Institude IUCAC. The result of serum lipid profile are summerized in Table 6. All rat groups except for casein fed rats resulted in no significant difference in TG value ranging from 14.5-17.3 mg/dl. Thre was no significant difference in total cholestrol content between all rat groups which recorded value ranging from 52.2-59.9 % mg/dl. This indicated that beef burger with added palm based fat fed to rats did not affect total cholestrol content in their blood serum. There was no significant difference (P<0.05) in LDL-cholestrol content between all treatment (10.3-13.5 mg/dl) except for casein diet which recorded the lowest value (8.0 mg/dl). The C treatment recorded the lowest value of HDL-cholestrol (40.7 mg/dl) compare to the red PF which was highest in HDL-cholestrol (49.7 mg/dl). This finding may be due to the existence of natural tocotrienol, tocopherol and carotenes in beef burger diets which promote higher levels of HDL-C in rat blood serums.

Table 6. Triacylglycerol and cholestrol profile in rat blood serum fed with different diets

Rat diets	Triacylglycerol (mg/dl)	Total cholesterol (mg/dl)	HDL cholestrol (mg/dl)	LDL cholestrol (mg/dl)
Beef Fat (C)	16.6 ± 2.0^{ab}	52.2 ± 3.8^{a}	40.7 ± 4.6^{b}	11.4 ± 2.5^{a}
Palm Fat (PF)	16.5 ± 1.7^{ab}	53.2 ± 5.0^{a}	49.7 ± 3.8^{a}	10.3 ± 2.3^{ab}
Red Palm Fat (red PF)	17.3 ± 1.3^{a}	59.9 ± 8.7^{a}	49.7 ± 5.4^{a}	11.4 ± 1.2^{a}
Fat Blend (FB)	14.5 ± 1.5^{b}	54.5 ± 6.8^{a}	48.1 ± 5.7^{ab}	13.5 ± 3.3^{a}
Casein (R)	12.1 ± 2.1^{c}	58.6 ± 6.5^{a}	45.4 ± 7.7^{ab}	8.0 ± 1.8^{c}

[a-c] Mean values within the same column bearing different superscripts different significantly (P<0.05)
Source: Wan Rosli *et al.,* 2007

Proximate analysis

Proximate analysis of raw materials were determined according to standard method described by the Association of Official Analytical Chemists (AOAC 1975 [a,b], 1984 [c,e], 2000 [d, f]). Table 7 shows the percentage of protein, fat, moisture and ash from the proximate analysis of raw materials from various products.

The proximate analysis can be divided into two group of studies based on a wet weight basis and dry matter basis. Studies of MacNeil *et al*. (1978), Babji *et al.* (1980) and Babji and Selvakumari (1989) calculated on a wet weight basis while Babji *et al.* (2007), Nur Azlina *et al.* (2007) and Marini *et al*. (2007) used dry matter basis.

The data showed that soy protein isolate (SPI) had the highest protein content (95.00% ± 1.71) followed by meat such as mackerel fish (89.09% ± 1.40) and beef (88.60% ± 0.27). Protein content in mechanically deboned poultry meat (MDPM) ranged from 11.90% for broiler back (BK) to 18.28% ± 0.19 for cooked fowl meat (CMDTM). Beef hamburger products ranged from 11.32% ± 0.07 to 19.44% ± 0.22. In MDPM, the protein level was lower due to the loss of collagen protein during the separation of meat from the bone (Babji *et al.,* 1980) while in the beef hamburger products resulted from the use of fillers and binders such as fat and starches (Babji and Selvakumari 1989). Percentage fat from locally processed beef burgers ranged from 24.67 ± 0.20 to 27.08 ± 0.11. These figures were among the highest, including MDCM (24.59 ± 0.58) which was due to the inclusion of both skin and adipose fat from broiler backs and necks (Babji *et al.,* 1980).

The proximate analyses of beef burgers formulated with palm based fats are shown in Table 8 . Beef fat burger contained 16.7 % protein followed by the fat blend (FB) at 16.2 %. The fat content of raw FB burger (21.9%) was significantly higher

Table 7. Comparison of proximate analysis of raw materials from various products

Products	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Skinless broiler neck (SN) [a]	15.30	7.90	76.70	1.00
Skinless broiler neck & back (SNBK) [a]	15.30	17.00	69.00	0.95
Broiler back (BK) [a]	11.90	24.10	63.10	0.87
Chicken (MDCM) [b]	13.04 ± 0.39	24.59 ± 0.58	62.44 ± 0.75	0.67 ± 0.04
Cooked fowl meat (CMDFM) [b]	18.28 ± 0.19	16.50 ± 1.06	63.16 ± 0.18	1.38 ± 0.14
Turkey (MDTM) [b]	16.28 ± 0.64	15.81 ± 0.14	65.92 ± 0.11	1.25 ± 0.06
Pure beef [c]	19.44 ± 0.22	1.92 ± 0.03	78.90 ± 0.02	1.19 ± 0.02
70:30 [c]	18.17 ± 0.22	0.55 ± 0.02	77.12 ± 0.06	5.41 ± 0.02
Beef burger (Angus) [c]	13.78 ± 0.22	24.67 ± 0.20	54.14 ± 0.22	2.28 ± 0.02
Beef burger (Fika) [c]	14.73 ± 0.15	25.35 ± 0.03	52.27 ± 4.62	2.35 ± 0.24
Beef burger (Ramly) [c]	13.54 ± 0.21	27.08 ± 0.11	51.16 ± 0.79	1.81 ± 0.06
Beef burger (Thrifty) [c]	11.32 ± 0.07	13.29 ± 0.12	56.52 ± 0.74	2.13 ± 0.17
Anchovy [d]	81.46 ± 0.98	2.82 ± 0.25	3.46 ± 0.30	4.75 ± 2.25
Mackerel [d]	89.09 ± 1.40	7.76 ± 0.28	4.22 ± 0.13	3.28 ± 0.37
Canned sardine [d]	59.25 ± 1.27	24.22 ± 1.51	5.79 ± 0.37	7.32 ± 0.40
Soy protein isolate (SPI) [e]	95.00 ± 1.71	0.62 ± 0.25	0.85 ± 0.08	3.78 ± 0.02
Meat [e]	88.60 ± 0.27	11.18 ± 0.16	0.61 ± 0.03	4.09 ± 0.01
Tempeh [e]	54.68 ± 5.69	22.41 ± 0.79	0.59 ± 0.01	1.79 ± 0.02
Milk casein [e]	87.50 ± 0.06	1.00 ± 0.01	11.00 ± 0.20	1.80 ± 0.03
Palm kernel cake (PKC) [f]	17.50 ± 0.30	10.70 ± 0.10	5.20 ± 0.00	4.10 ± 0.00
Fermented palm kernel cake (fPKC) [f]	24.70 ± 0.20	4.10 ± 0.40	8.80 ± 0.10	5.80 ± 0.00

Sources: [a] MacNeil *et al.,* 1978, [b] Babji *et al.,* 1980, [c] Babji and Selvakumari 1989, [d] Babji *et al.,* 2007, [e] Nur Azlina *et al.,* 2007, [f] Marini *et al.,* 2007

Table 8. Proximate analyses of raw beef burgers

Burgers	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Beef Fat (C)	16.7± 0.1[a]	19.4 ± 0.3[c]	57.0 ± 0.8[a]	2.1± 0.1[a]
Palm Fat (PF)	15.9± 0.2[b]	20.9 ± 0.2[ab]	56.6± 0.3[a]	2.2± 0.1[a]
Red Palm Fat (red PF)	15.8 ± 0.3[b]	20.6 ± 0.6[bc]	56.7 ± 0.1[a]	2.2± 0.1[a]
Fat Blend (FB)	16.2 ± 0.3[b]	21.9± 0.3[a]	56.0 ± 0.2[a]	2.2± 0.1[a]

a-c Mean values within the same column bearing different superscripts different significantly (P<0.05)

Table 9. Proximate analyses of formulated rat diets

Rat Diet	Burgers/reference	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
1	Beef Fat (C)	10.1± 0.1[a]	8.0± 0.2[a]	5.1 ± 0.3[a]	4.5 ± 0.3[a]
2	Palm Fat (PF)	10.0± 0.2[a]	8.4 ± 0.1[a]	5.0 ± 0.2[a]	4.5 ± 0.1[a]
3	Red Palm Fat (red PF)	9.9 ± 0.6[a]	8.2 ± 0.2[a]	5.1 ± 0.2[a]	4.3 ± 0.3[a]
4	Fat Blend (FB)	9.8± 0.3[a]	8.1 ± 0.3[a]	5.1 ± 0.1[a]	4.3 ± 0.2[a]
5	Casein (R)	9.9 ± 0.4[a]	8.3 ± 0.3[a]	4.9 ± 0.2[a]	4.3 ± 0.2[a]

a Mean values within the same column bearing different superscripts different significantly (P<0.05)

(P<0.05) than red PF burger (20.06%). There was no significant difference in moisture and ash content between all raw burgers. However, there was no significant difference in proximate composition between all rats diet (Table 9). The data shows that protein and fat content of all rat diet achieved 10 and 8% , respectively as recommended by AOCS (1992).

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