Changes of Chemical Composition and Aflatoxin Content of Peanut Products as Affected by Processing Methods

Pengaruh Cara Pengolahan terhadap Komposisi Kimia dan Kadar Aflatoksin Produk Olahan Kacang Tanah

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ABSTRAK

Produksi kacang tanah di Indonesia terutama dimanfaatkan sebagai bahan pangan, sehingga aspek nilai gizi dan kontaminasi aflatoksin menjadi isu penting ditinjau dari ketahanan dan keamanan pangan. Kacang tanah mengalami perubahan fisik dan kimia selama pengolahan yang mengakibatkan nilai gizinya berkurang dan tidak aman dikonsumsi. Oleh karena itu, perlu dilakukan penelitian pengaruh cara pengolahan terhadap komposisi kimia dan kandungan aflatoksin produknya. Polong kering yang diperoleh dari hasil panen petani di Ponorogo, Jawa Timur disimpan selama satu bulan, kemudian diolah menjadi kacang goreng, sambel pecel, bungkil kacang, bungkil kacang goreng, tempe bungkil kacang dan tempe bungkil kacang goreng. Penelitian untuk mengetahui komposisi kimia dan kandungan aflatoksin bebrapa hasil olahan kacang tanah tersebut dilakukan dengan rancangan acak lengkap, tiga ulangan. Analisis kandungan aflatoksin B_1 dilakukan dengan metode ELISA. Biji kacang tanah mengandung 26,3% protein (bk) dan 50,4% lemak (bk), kandungan aflatoksin pada biji relatif rendah (9,1 ppb). Peningkatan kadar protein tertinggi diamati pada pengolahan kacang tanah menjadi tempe bungkil kacang, diikuti tempe bungkil kacang goreng, bungkil kacang, dan bungkil kacang goreng, sedangkan kadar lemak turun pada semua produk berkaitan dengan kadar air yang cukup rendah (5,6%), tidak terdeteksi infeksi *Aspergillus flavus,* dan persentase biji utuh tinggi (73,1%). Pada pengolahan kacang goreng dan bungkil kacang goreng, kandungan aflatoksin berkurang masing-masing sebesar 26,4% dan 41,8%, sementara pada sambal pecel dan bungkil kacang goreng kadar lemak relatif sama nilainya. Kandungan aflatoksin meningkat dua kali pada pengolahan tempe bungkil kacang, namun berkurang 38,9% setelah menjadi tempe bungkil kacang goreng. Selain tempe bungkil kacang, lima produk kacang lainnya mengandung aflatoksin di bawah ambang batas aman yang diijinkan, yakni 15 ppb, sehingga aman untuk dikonsumsi.

Kata kunci: aflatoksin, komposisi kimia, produk kacang tanah.

ABSTRACT

Peanut production in Indonesia is predominantly used for food, thus information on nutritional aspects and aflatoxin contamination in peanuts is essential in terms of food security and safety. As changes may occur during processing, the effects of processing methods on chemical composition and aflatoxin content in selected peanut products were studied. The dried peanut pods collected from a farmer in Ponorogo, East Java were stored for one month, and then the kernels were prepared into fried peanut (*kacang goreng*), peanut sauce (*sambel pecel*), peanut press cake (*bungkil kacang*), fried-pressed peanut (*bungkil kacang goreng*), fermented peanut press cake (*tempe bungkil kacang*), and fried peanut tempe (*tempe bungkil kacang goreng*). The trial to determine chemichal composition and aflatoxin of some these processed peanut product was arranged in a randomized complete design with three replicates. ELISA method was applied for aflatoxin B_1 analysis. The results showed that peanut kernels contained 26.3% protein (dw) and 50.4% fat (dw) with relatively low aflatoxin B_1 content (9.1 ppb) due to low moisture level (5.6%), no *Aspergillus flavus* infection and high sound/intact kernels (73.1%). Peanuts processed into *tempe bungkil kacang* showed the highest increase in protein content, followed by *tempe bungkil kacang goreng*, *bungkil kacang*, and *bungkil kacang goreng*, while fat contents decreased in all products. Processing into *kacang goreng* and *bungkil kacang goreng* decreased aflatoxin B_1 by 26.4% and 41.8%, respectively, while no significant differences were noted in *sambal pecel* and *bungkil kacang*. Aflatoxin B_1 increased two-fold during the preparation of *tempe bungkil kacang*, however it significantly decreased by 38.9% after deep-fried. Excluding peanut tempe, all peanut products contained aflatoxin B_1 below the permitted level (15 ppb), therefore they are safe for consumption.

Keywords: aflatoxin, chemical composition, peanut products.

INTRODUCTION

Peanut is nutritionally important due to its high lipid and protein contents that range from 40-50% and 20-40%, respectively (Sebei *et al.* 2013). About 85% of peanut available in Indonesia is used for food with a consumption level of 0.27 kg/capita/year (Resapati *et al.* 2014). Peanut is mostly

consumed as sauces for salads (Nugraha *et al.* 2018), and as snacks (boiled, fried, roasted, flour coated, pastry fillers, confectionary, traditional snacks). To a lesser extent, it is also consumed as fermented products in particular areas (*oncom,* a peanut press cake tempe) and industrial products like oil, peanut butter, and flour (Ginting and Rahmianna 2015). Therefore, the availability of good quality peanut as food ingredient is of concern with respect to nutrition and food safety.

Peanut is highly susceptible to aflatoxin contamination caused by toxigenic strains of *Aspergillus flavus*, *A. parasiticus* and *A. nomius* that may occur either in the field or being stored (Amaike and Keller 2011, Abrar *et al*. 2013). High moisture (a_w 0.78-0.98), temperature (20-40 °C), and relative humidity (>80%) are favourable conditions for the moulds to produce aflatoxins (Aini 2012, Khodatin *et al.* 2014, Pratiwi *et al*. 2015). Such hot and humid air conditions that are common in tropical countries like Indonesia as well as traditional storage methods applied (Ginting and Rahmianna 2015) may cause aflatoxin contamination in peanut and peanut food products.

Aflatoxins are hazardous to humans and animals (Bryden 2012) as they have capacities as carcinogenic (hepatocellular carcinoma), mutagenic (Bhat *et al*. 2010, van den Berg *et al*. 2011, Kew 2013), teratogenic, depressive immuno response, and also may cause impair child growth (Makori *et al.* 2018), and female reproduction (Santos *et al*. 2013). Aflatoxin B_1 is the most toxic and frequently present both in food and feed (Al-Abdalall *et al*. 2009, Reddy *et al*. 2010). Codex Alimentarius set a maximum level of 15 ppb for total aflatoxins (B_1, B_2, G_1 and G_2) in peanuts for further processing (Codex Alimentarius Commission 2014), 20 ppb for USA (Torres *et al*. 2014), and as low as 4 ppb for the European Union (Wu *et al*. 2013), while Indonesia establishes 15 ppb for aflatoxin B_1 in peanut food products and 20 ppb for total aflatoxins (Rahayu 2011).

Processing of peanuts into food products normally involves heat treatment, the use of water, spices, and microorganisms (fermentation) that may affect the nutrient and aflatoxin contents. Aflatoxins are heat resistant and less water soluble (Abrar *et al*. 2013), hence they cannot be eliminated 100% during processing. Most existing studies in Indonesia report the final aflatoxin contents in peanut food products collected from the markets (Razzazi-Fazeli *et al*. 2004, Ambarwati *et al*. 2011, Rahmianna and Yusnawan 2015), while information on their content or reduction during different food processing is still lacking. Limited study on aflatoxin reduction was noted during the preparation of peanut oil, *oncom* and peanut butter (Fardiaz 1991), and selected products derived from peanut kernels collected from local market (Ginting *et al.* 2018). Thus, a known source of peanut origin from a collaborator farmer will be used for studying both the nutrient and aflatoxin changes during processing.

A number of studies also revealed that peanut samples and their products contaminated with aflatoxin B_1 >15 ppb, particularly for those kernels obtained from retailers at traditional markets, peanut sauce and fermented peanut press cake (Dharmaputra *et al.* 2007, Rahmianna *et al*. 2007a, Dharmaputra *et al.* 2013, Aisyah *et al*. 2015). Conversely, peanut pods and kernels sampled from farmers and collectors as well as oven roasted peanuts and flour-coated peanuts showed aflatoxin B_1 content <15 ppb (Dharmaputra *et al.* 2007, Rahmianna *et al*. 2007a). These facts reflect that farmer practices both in pre and postharvest handling, initial quality of peanut as food ingredient and treatments during processing may contribute to such differences in aflatoxin contents. Therefore, this research activity was performed to study the effects of different processing methods on nutrient and aflatoxin contents of selected peanut food products using peanut kernels produced by a collaborator farmer. This study is essential for nutrient and aflatoxin control during food preparation.

MATERIALS AND METHODS

A peanut cultivar of Local Ponorogo was obtained from a collaborator farmer. It was cultivated in rainfed area of Ponorogo Regency, East Java Province during wet season. Harvesting was undertaken at 85 days after sowing, and then the pods were manually separated. Fresh pods were sun-dried until the moisture content was about 7%, shelled and the kernels were stored in a permeable plastic bag (*glangsi*) at ambient temperature and relative humidity for about one month in the beginning of dry season (April-May). The method resembles the common practice by local farmers. A period of up to one month is usually needed by farmers to market the harvested peanuts (Ginting and Rahmianna 2015).

Stored peanut kernels were then processed into six kinds of product, namely a) fried peanut or *kacang goreng*, b) peanut sauce or *sambel pecel*, c) pressed peanut cake or *bungkil kacang*, d) fried *bungkil kacang* or *bungkil kacang goreng*, e) fermented *bungkil kacang* or *tempe bungkil kacang*, and f) fried *tempe bungkil kacang* or *tempe bungkil kacang*

goreng. The following steps of processing were conducted for each product: a) *Kacang goreng*: soaking the kernels in boiled water (45 min), removing the seed coat, oven drying (80 °C, 20 min), soaking the dried kernels in a solution containing crushed garlic and salt, deep-frying (120 °C, 15 min), removing the excess of oil by centrifuge machine; b) *Sambel pecel*: washing the peanut kernels, deep-frying at 120 °C for 10 min, grinding and blending with water, salt, palm sugar, and spices; c) *Bungkil kacang*: oven drying peanut kernels at 120 °C for 20 min, and hydraulic pressing; d) *Bungkil kacang goreng*: soaking of *bungkil kacang* for 10 min in a solution containing crushed garlic and salt, deep-frying at 120 °C for 15 min, and removing the excess of oil by centrifuge machine; e) *Tempe bungkil kacang*: grinding of *bungkil kacang*, soaking for 24 h, washing, steaming for 1.5 h, cooling for 4 h, inoculating with a commercial starter for peanut tempe, and facilitating the fermentation at room temperature for 24-36 h; f) *Tempe bungkil kacang goreng*: cutting of *tempe bungkil kacang* into small pieces (5 cm x 4 cm x 1.5 cm), steeping in wheat flour batter containing salt and crushed garlic, and then deep-frying at 120 °C for 10 min. The producing process of such products, except for *tempe bungkil kacang*, was performed at the Iletri Laboratory of Food Chemistry and Technology, Malang using a randomized complete design with three replicates. Tempe *bungkil kacang* was prepared by a selected commercial tempe producer in Malang.

Observations were done for physical quality (intact, shriveled, and damaged kernels) of peanut kernels according to National Standardization Agency of Indonesia(1995). Chemical composition of peanut kernels and products, included: a) moisture and ash contents (gravimetry method), and fat content (direct extraction method) referring to National Standardization Agency of Indonesia (1992), b) protein content followed the method of Micro Kjeldahl (AOAC 2005). Infected peanut kernels by *A. flavus* was observed through putting 100 peanut kernels in 10 petridishes containing *Aspergillus flavus* and *parasiticus* agar (AFPA) media. The number of mould infected kernels with orange/dark yellow colour was noted on the fourth day and calculated in percentage (Ginting and Rahmianna 2015). The Enzyme-Link Immunosorbent Assay (ELISA) method as referred to Lee *et al*. (2004). Data generated from all treatments were statistically analyzed using analysis of variance (Anova), followed by LSD test for analysis of mean differences between treatments at the probability level of 0.05.

RESULTS AND DISCUSSION

Physical Quality, *Aspergillus flavus* Infection and Aflatoxin Content of Peanut Kernels

Peanuts used in this study showed a low number of shriveled kernels (2.4%) as seen in Table 1, suggesting an optimal maturity for harvesting (Rahmianna *et al*. 2015a). However, the level of damaged kernels was relatively high (24.5%). Broken kernels due to mechanical damage, insect and mould attacks, as well as undergoing changes such as sprouting, rotten, bad smell and discolourization belong to damaged kernel (National Standardization Agency of Indonesia 1995). Such changes were possibly took place during one-month storage in a permeable plastic bag that resulted in high number of damaged kernels. This was also observed in peanut kernels stored in an opened wooden box with 80.9% of damaged kernel after four months compared to those stored in a sealed plastic bag (1.3-1.9%) (Ginting 2006). Meanwhile, a lower number of damaged kernels (4%) was noted for one-month storage of peanut in jute bag (Mutegi *et al*. 2013). Different kernel moisture contents and surrounding air conditions (temperature and relative humidity) may lead to such differences in physical quality during storage (Mutegi *et al*. 2013). The damaged kernels have a higher risk for aflatoxin contamination compared to sound/intact kernels (Rahmianna *et al*. 2015a, Waliyar *et al*. 2015, Siruguri *et al*. 2018). In this study, the number of shriveled kernels have met the national peanut standard quality (maximum level of 4%) as established by National Standardization Agency of Indonesia (1995). However, the damaged kernels were much higher than the maximum limit (2%).

Table 1 shows that the moisture content of

Table 1. Physical quality, moisture content, *A. flavus* infection and aflatoxin content of peanut kernels

Parameters	Values
Sound/intact kernels (%)	73.1 ± 2.4
Shriveled kernels (%)	2.4 ± 0.9
Damaged kernels (%)	24.5 ± 1.5
Moisture content (%)	5.6 ± 0.1
A. flavus infection (%)	0
Aflatoxin content (ppb)	9.1 ± 0.1

peanut kernels was considerably low (5.6%). This may associate with peanut storage in a permeable plastic bag, which easily absorbs moisture as well as release moisture from the kernels to the surrounding air to reach the equilibrium moisture content. Similar finding was reported in peanut kernels stored in an opened wooden box (Ginting 2006), which gave lower moisture content (5.5%) relative to those stored in a sealed plastic bag (5.8%). Muntegi *et al*. (2013) also noted a decrease in moisture content from 5.6% to 5.3% for peanut kernels stored in a jute bag. The level of peanut moisture (5.6%) was much lower than the maximum level set for national peanut standard quality ($\leq$8%) (National Standardization Agency of Indonesia 1995).

Infection of *A. flavus* in peanut kernels was not detected and low initial aflatoxin B_1 content (9.1 ppb) was observed (Table 1), which much lower than the permitted limit (15 ppb). The presence of aflatoxin might be due to a previous contamination of *A. flavus* occurred during preharvest. This may associate with drought stress at the final generative phase, high soil temperature, the availability and infection of toxigenic *A. flavus* on the peanut pods and kernels in the soil (Rahmianna *et al.* 2007b). However, subsequent drying up to moisture content below 7% after harvesting and fairly dry storage conditions may contribute to the absence of *A. flavus* infection in peanut kernels and low aflatoxin production during storage, even though the number of damaged kernels was relatively high (Table 1).

Aspergillus flavus would start growing at a moisture content of 8-10% and optimum to produce aflatoxin at a moisture content of 10% or higher at around 82% relative humidity (Torres *et al*. 2014). Aflatoxin B_1 positively correlated ($r = 0,72$) with the moisture content of peanut kernels (Rahmianna *et al*. 2007a), suggesting that *A. flavus* is sensitive toward moisture changes. Peanut kernels stored in an opened wooden box for four months were also reported to have low level of aflatoxin B_1 (<10 ppb), even though the number of damaged kernels has already been 80.9% (Ginting 2006) due to low initial moisture content (<7%) and dry surrounding air conditions (35-37 °C and 53-73% relative humidity). Safe storage for peanut kernel is suggested at moisture content of 7% with maintained temperature of 25-27 °C and 70% relative humidity (Torres *et al*. 2014).

Chemical Composition of Peanut Kernels and Peanut Products

Significant changes in moisture content of peanut kernels occurred during processing into peanut products (Table 2). The lowest moisture contents were seen in *kacang goreng* and *bungkil kacang goreng* associated with the release of moisture during frying. Meanwhile, the highest moisture content was seen on *tempe bungkil kacang* due to soaking, steaming and fermentation process. No significant difference in moisture content was observed between *tempe bungkil kacang* and its fried product since both were soaked in watery seasoning mixture of wheat flour, salt and garlic prior to frying. *Sambel pecel* contained moisture (13.0%) in between those of *kacang goreng* and *tempe bungkil kacang goreng*. Frying of peanut kernels during preparation of *sambel pecel* would decrease the moisture content, however grinding and blending the kernels with palm sugar, spices, and water consequently increased the final moisture content. The levels of moisture in peanut products would dictate their storability and quality as the presence of high moisture (>8%) would induce the growth of mould as well as fat oxidation (rancidity).

The peanut kernels contained ash about 2.6% (dw), which represent the mineral contents, particularly K, Na, P, Ca, and Mg (Atasie *et al*. 2009). This value was slightly lower than that of Mahesa and Kancil varieties (2.9% dw) (Ginting 2006) and Iletri peanut germplasm (2.73% dw) (Nugrahaeni 2018). Peanut products showed significant differences in ash contents compared to that of peanut kernels. *Sambel pecel* had the highest ash content due to the addition of palm sugar and spices, like red chili, garlic, citrus leaves, and tamarind. *Kacang goreng* and *bungkil kacang goreng* also showed a slightly higher ash content as a result of using garlic, salt and vegetable oil in processing. The lowest ash content was seen in *tempe bungkil kacang* as minerals may be leached out during overnight soaking and steaming (Sarkar *et al.* 1998, Nassar *et al.* 2008). In addition, calcium decreased during tempe fermentation as well as phytic acid containing phosphorus as a result of phythase activity produced by *Rhizopus* sp. (Astuti 2000). A decrease in ash content (44.8%) was also noted by Fadahunsi and Sanni (2010) during bambara-nut tempe fermentation.

The protein content of peanut kernels was 26.3% (dw) which was similar to that (23.5-26.6%) reported by Campos-Mondragón *et al*. (2009) and slightly lower than that of Iletri peanut germplasm *i.e.* 27.5% (dw) (Nugrahaeni 2018). Processing significantly affected protein content of peanut products. Fermentation slightly increased the protein content from 31.6% to 34.9% (dw) as noted in *tempe bungkil kacang*, giving the highest value among all products. In fact, total N or total protein seems to be similar

Table 2. Chemical composition of peanut kernels and products

Peanut kernels and products	Moisture (%)	Ash (% dw)	Protein (% dw)	Fat (% dw)
Peanut kernels	5.6 ± 0.1 c	2.6 ± 0.1 d	26.3 ± 1.1 d	50.4 ± 1.2 a
Kacang goreng	1.9 ± 0.5 *e*	3.5 ± 0.1 b	23.8 ± 1.3 *e*	47.6 ± 0.7 b
Sambel pecel	13.0 ± 1.2 b	4.6 ± 0.2 a	17.0 ± 0.9 f	32.4 ± 2.1 d
Bungkil kacang	4.1 ± 0.8 cd	3.1 ± 0.1 c	31.6 ± 0.6 b	42.3 ± 1.7 c
Bungkil kacang goreng	2.2 ± 0.4 de	3.8 ± 0.2 b	29.0 ± 0.8 c	47.1 ± 1.2 b
Tempe bungkil kacang	46.5 ± 2.5 a	2.1 ± 0.1 *e*	34.9 ± 0.1 a	48.1 ± 1.2 b
Tempe bungkil kacang goreng	45.3 ± 1.9 a	2.5 ± 0.1 d	32.3 ± 0.5 b	46.8 ± 0.1 b
LSD 5%	2.0	0.2	1.3	1.9
CV (%)	6.5	4.0	2.6	2.4

Values presented are means ± SD; dw = dry weight; Values in the same columns followed by different letters are significantly different at 5% level of LSD test.

before and after fermentation, even though soluble protein increased sharply as a result of mould protease activity (Astuti *et al.* 2000). Therefore, a slight increase in protein content in this study may due to a change in composition of the dry matter. About 10% loss of dry matter was reported during fermentation as carbohydrate and fat as a carbon and energy source, respectively are utilized for the growth of mould (de Reu *et al.* 1995, Nassar *et al.* 2008). Also, mould biomass protein may contribute to an increase of protein content in tempe, which likely associates with the growth rate of mould (de Reu *et al.* 1995, Nassar *et al.* 2008).

Oncom, a fermented defatted peanut originally from West Java (Hariyanto 2017) contained protein about 19% (dw) (Yulifianti *et al*. 2015) and 27.2% (dw) (Sofyan, 2003), which was lower than that of *tempe bungkil kacang* prepared in this study (34.9% dw). Meanwhile, Cornelia *et al*. (2012) reported a slightly higher protein content in red *oncom* (37.4% dw). Different raw materials/ingredient of *tempe bungkil kacang* from *oncom* and processing methods may contribute to such differences in protein content.

A significant increase in protein content was also observed in *bungkil kacang* as well as *bungkil kacang goreng*. The previous study revealed that the fat content could be reduced by 20% through pressing out the kernel oil, thereby increased the protein content by 16% (Yulifianti *et al*. 2015). The lowest protein content was seen in *sambel pecel* due to the addition of palm sugar up to 40%, and thus lowering the proportion of protein derived from peanut kernels.

The fat content of peanut kernels was 50.4% dw (Table 2), which was much higher than those of Kancil and Mahesa varieties (45-47% dw) (Ginting 2006) as well as Iletri germplasm (47.5% dw) (Nugrahaeni 2018). Processing significantly decreased the fat contents in all peanut products (Table 2). Adding palm sugar in preparation of *sambel pecel* resulted in the lowest fat among other products. A significant decrease in fat content was also noted in *bungkil kacang* compared to that of peanut kernels. However, *bungkil kacang goreng* and *kacang goreng* showed a similar fat content. During pressing, relatively smaller amounts of fat could be removed (8-13%) from the kernels compared to previous study that may up to 20% (Yulifianti *et al*. 2015) due to a lower capacity of the hydraulic press used in this study (15 tons). However, the fat content in *bungkil kacang* goreng increased by 5% after subsequent deep-frying process. Therefore, roasting instead of deep-frying after pressing out the kernel oil can be suggested to maintain low-fat content in the final product of *bungkil kacang goreng*.

Tempe bungkil kacang showed an increase in fat content after fermentation relative to *bungkil kacang* (Table 2). In fact, *Rhizopus* sp. possess lipase that hydrolyzes lipids into fatty acids (Owens *et al.* 2014), suggesting that fat in the substrate may be decomposed during fermentation. Hering *et al.* (1991) found no significant loss of total fat content during soybean tempe fermentation, but slightly decreased during *oncom* fermentation (Owens *et al.* 2014). Therefore, the fat content possibly increased due to the *novo* fatty synthesis by *Rhizopus* sp. (Hering *et al.* 1991, Suleiman *et al.* 2018). *Rhizopus* sp. belongs to oleaginous moulds, the microorganisms which can produce or accumulate lipids that are rich in unsaturated fatty acids, particularly oleic acid (Hassanien *et al.* 1986, Sahara *et al.* 2016, Suleiman *et al.* 2018). The fat content of tempe *bungkil kacang* found in this study was much higher compared with that of *oncom* (9.2% dw) (Sofyan 2003). Commercial defatted peanut which is commonly used as a raw material for

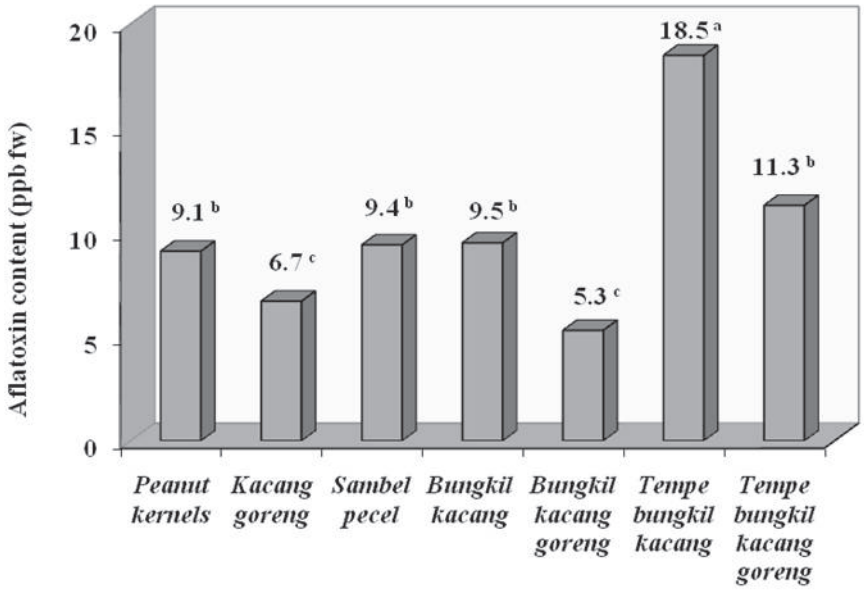

Figure 1. Aflatoxin B_1 content in peanut products compared to initial aflatoxin B_1 content in peanut kernels. Values followed by different letters are significantly different at 5% level of LSD test

producing *oncom* contains very small amount of fat (4.6%). After deep-frying, the fat content of *tempe bungkil kacang goreng* was not significantly different to the non-fried one because the seasoned flour batter cover was removed prior to analysis.

Aflatoxin B_1 Content of Peanut Products

Aflatoxin content for each peanut product is presented in Fig. 1 in fresh weight (fw) concerning the safe limit for human consumption. Processing methods significantly affected aflatoxin contents in final peanut products. Both fried peanuts (*kacang goreng* and *bungkil kacang goreng)* had the lowest level of aflatoxin B_1 with a reduction of 26.4% and 41.8%, respectively. Decomposition of aflatoxin take places at a range temperature of 237 to 306 °C (Jalili 2016, Pankaj *et al*. 2018) and aflatoxin B_1 has a melting point of 268-269 °C (Quadri *et al*. 2013), thus it is considerably heat resistant. However, heat treatments may destruct the aflatoxin chemical structures (Siwela *et al*. 2011) to some extents, thereby reduce the amounts and toxicity levels. About 50% of aflatoxin B_1 reduction was noted in boiling peanut for 30 min (Diedhiou *et al*. 2012), 73% in deep-frying peanut at 150 °C for 2 min (Rahmianna *et al*. 2015b), 37% in roasting peanut at 160 °C (Siwela *et al*. 2011), and 30-45% at 150 °C for 30 min (Kabak 2009), as well as 80.2% in oven-drying peanut at 130-150 °C (Arzandeh and Jinap 2011).

The combination of heat treatments and the use of spices, like garlic and salt also showed an increase in aflatoxin degradation (Farah *et al*. 1983, Farag *et al*. 1989) as performed in the preparation of both *kacang goreng* and *bungkil kacang goreng*. A reduction of 46.5% of aflatoxin B_1 was noted for sample treated with aqueous garlic extract for 30 min and up to 68.3% for 1 h (Negera and Washe 2019). Ansori (2004) reported a slightly higher reduction of aflatoxin B_1 content in *bungkil kacang goreng* (56.9%) compared to the finding of this study (41.8%). It was possibly due to a different temperature and time applied during heating or frying. The aflatoxin contents of both *kacang goreng* and *bungkil kacang goreng* found in this study were less than 15 ppb, therefore safe for consumption.

The level of aflatoxin B_1 in *sambel pecel* and *bungkil kacang* was similar and was slightly lower than that of the raw peanut kernels (Fig. 1). The addition of palm sugar and spices, particularly red chili in peanut sauce may be attributed to a slight increase in aflatoxin B_1 as expectedly it should decrease during deep-frying of the kernels. Anthony *et al*. (2012) reported that fresh red chili may contain 2-12.4 ppb of aflatoxin B_1 and around 11.7 ppb for total aflatoxins (Khan *et al*. 2014). A significant increase (two-fold) of aflatoxin B_1 was also noted by Farawahida *et al*. (2017) in peanut sauce after the ground-fried peanut kernels was mixed with commercial chili powder. Nevertheless, aflatoxin contents in both *sambel pecel* and *bungkil kacang* in current study were yet below the permitted level (15 ppb). Previous studies observed a considerable range of aflatoxin levels (0-221 ppb) in *sambal pecel* samples collected from local markets (Rahmianna *et al*. 2015b). Similar finding was also reported for *bungkil kacang* sample (126 ppb) (Rahmianna *et*

al. 2015b) as low quality of peanut kernels is normally used as the ingredient.

Tempe bungkil kacang had the highest content of aflatoxin B_1 (Fig. 1) with an increase of 103.3% relative to the initial level in peanut kernels. Conversely, fermentation during the preparation of black and red *oncom* showed a considerable decrease in aflatoxin B_1 content (86.6% and 58.9%, respectively) (Rahmianna *et al*. 2015b). This may due to a longer fermentation time (48-72 h) applied for *oncom* making (Fardiaz 1991, Iskandar *et al*. 2010) than *tempe bungkil kacang* prepared in this study that was only 24-36 h. Fardiaz (1991) who conducted an *oncom* study also noted an increase in aflatoxin content (4.3%) during 24-hour incubation of inoculated peanut with both *Aspergillus flavus* and *Rhizopus oligosporus*. However, it constantly decreased after 48 h and 72 h as more time available for *R. oligosporus* to chemically and enzymatically degrade aflatoxin as well as to compete with *A. flavus* as both moulds are antagonist (Kusumaningtyas *et al*. 2006, Endarwati and Kusumaningtyas 2017). In addition, the starter normally used for peanut tempe in Malang is not a pure culture of *R. oligosporus* as used by the latter study, but a mixed cultures of *Rhizopus* spp, *Mucor* spp, yeast and bacteria (Pamungkas *et al*. 2017), thus might be less effective to compete with *A. flavus*.

Tempe bungkil kacang prepared at present study contained much lower aflatoxin B_1 (11.3 ppb) than that of *oncom* and peanut tempe (67 ppb and 20 ppb, respectively) collected from local markets (Rahmianna *et al*. 2015b), particularly due to a low quality of peanut press cake used. After deep-frying (120 ^oC, 10 min), raw *tempe bungkil kacang* that covered with wheat flour batter containing salt and crushed garlic showed a significant decrease in aflatoxin content (38.9%) (Fig. 1) up to a safe level for consumption (<15 ppb). Meanwhile, a higher aflatoxin content was noted in a fried-*oncom* sample (41 ppb) (Rahmianna *et al*. 2015b), suggesting that ingredients and processing methods entirely affect the final aflatoxin content in the products.

CONCLUSION

Processing methods showed significant changes in protein, ash, fat, and aflatoxin contents of selected peanut products. The highest increase in protein content was seen in *tempe bungkil kacang*, while fat contents decreased in all products. The aflatoxin B_1 content decreased by 26.4% and 41.8%, respectively when peanut kernels were processed into *kacang goreng* and *bungkil kacang goreng*, while no significant reduction was obtained in *sambal pecel* and *bungkil kacang*. Aflatoxin B_1 increased by 103.3% in *tempe bungkil kacang*, however it decreased by 38.9% after deep-fried. Excluding *tempe bungkil kacang*, all peanut products contained aflatoxin B_1 below the permitted level (15 ppb), therefore they are safe for consumption.

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