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Shelf-stable Dried Okara from the Wet By-product of Philippine Soybean Curd Processing

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Okara is the wet by-product of silken soybean curd (*taho*) processing and other soybean processing procedures. It has a short shelf life of 12 h under Philippine ambient temperature (30 °C). Without further processing, it is generally used as feed or thrown as waste due to rapid spoilage. A two-stage drying scheme which utilized a manually-operated vertical screw-type press and mechanical dryer was applied to wet okara obtained from a producer of silken tofu. The physicochemical, proximate, microbial, sensory, and rancidity parameters of dried okara were evaluated within its estimated shelf life. Drying of okara to about 5% moisture content extended its shelf life at 30 °C to almost 6 months when packed under vacuum in laminated PET/FOIL/PE (119 µm). End of shelf life was based on rancid odor through sensory evaluation. Shelf stable dried okara was described as yellowish cream, granular powder with slightly sweet, nutty, and moderately beany odor and taste. The proximate composition of freshly dried okara consisted of >20% protein, >10% fat, and >50% dietary fiber. The value added dried okara did not show any strong beany taste which normally limits the use of other dried soybean products as ingredient, thus, can be utilized as a functional ingredient in various food products. Dried okara can be incorporated into food products to increase their protein and dietary fiber content.

Key words: by-product, drying, okara, shelf life, soybean

INTRODUCTION

In the Philippines, amongst the significant industries utilizing soybeans include tofu (firm soybean curd or *tokwa*); *taho* (silken tofu/soft soybean curd sold as sweetened dish), and soymilk processing industries (O'Toole 1999; Bureau of Agricultural Statistics 2011). The difference between firm and silken tofu is primarily related to the water content of the formed soybean curd (Paino & Messinger 1991), with firm tofu containing lower amount of water. The production of firm tofu includes curd breaking and pressing which removes water from the curd (Chang 2006). In producing firm tofu, the coagulant is stirred quickly and vigorously into the hot soymilk then the curds are broken and pressed. Tofu texture becomes firmer and water content decreases as the pressure or weight applied becomes heavier during pressing (Liu 1997). As early as 2011, the soybean resource of the country from local production and import sources already reached about 50,000 metric tons (BAS 2011). If half of these soybean resources were utilized for soybean processing and about 1 kg of wet okara is obtained per equivalent weight of soybeans (Ma et al. 1997, O'Toole 1999), it can be estimated that nearly 25,000 metric tons of wet okara was produced on the same year.

Wet okara is obtained after extraction of the water extractable fractions used to produce soymilk and tofu (O'Toole 1999). The quality of okara that will be obtained

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from soybean processing may be dependent on the efficiency of soymilk extraction process. The extraction pressure, pressing time, whether the soybean slurry is heated prior to extraction, and if the pressed okara is re-washed and re-pressed are some of the factors that affect the okara composition (Liu 1997). For example, for tofu production using Chinese method, soybean slurry is filtered cold prior to soymilk heating while the Japanese method involves extraction of soymilk from a cooked soybean slurry (Liu 1997; Chang 2006). It has been reported that heating facilitates soymilk extraction (Liu 1997) and provides higher yields of protein and lipids in the soymilk (Toda et al. 2007). After pressing, it has been reported that okara contains about 78% water and 22% solids (Liu 1997). The more efficient extraction of soymilk would result to lower nutrient content of the okara because it has been included in the soymilk which was extracted.

Currently, the okara is essentially utilized as local feed (BAS 2011) but is also being used as extender for minced meat in recipes like the local *lumpiang shanghai* or spring rolls and meatballs (Ligot et al. 1994). Okara is partly burnt as waste in Japan while it is used for landfills in Hong Kong (O'Toole 1999). Although generally considered as a waste product, okara can still be considered a potential source of protein and dietary fiber at about 20% and 50% by weight (dry basis) (Watanabe & Kishi 1984), respectively. Experimentally, okara has been used as ingredient in bread, biscuits, and meat products to utilize its protein and dietary fiber content (Wickramarathna & Arampath 2003; Turhan et al. 2007; Grizotto et al. 2010). There have been studies that investigated the health benefits of dietary fiber from okara that further promote its potential as a food ingredient (Katayama & Wilson 2008; Chen et al. 2010). The health benefits of dietary fiber include the prevention and mitigation of type 2 diabetes, cardiovascular disease and colon cancer (Kaczmarczyk et al. 2012). Dietary fiber reduces the risk of hyperlipidemia, hyperglycemia, and hypercholesterolemia by modulating food ingestion, digestion, absorption and metabolism (Kaczmarczyk et al. 2012; Villanueva et al. 2011). Villanueva et al. (2011) reported that the main components of okara, namely dietary fiber and protein, could be related with the cholesterol and total lipids decrease in the plasma and liver of the high-fat fed hamsters. Components found in okara such as isoflavones, lignans, saponins, and phytates have various therapeutic functions including prevention of cardiovascular diseases, antioxidant activity, and prevention of certain types of cancer (Head 1997; Li et al. 2012). Twelve potent acid resistant lactic acid bacteria strains were isolated from okara and two of these strains showed antioxidant property upon application to skim milk (Badarinath et al. 2010).

Despite the health benefits offered by wet okara, on its unprocessed form, it is a highly perishable commodity (Aguado 2010) thus it should be subject to some form of processing to make it more shelf-stable. Drying has been reported to increase the shelf life of okara (Coronel & Tobinaga 2004; Lescano et al. 2005; Sengupta et al. 2012). Spouted bed dryer was utilized by Lescano et al. (2005) and Coronel & Tobinaga (2004) in drying okara. Sengupta et al. (2012) used vacuum tray dryer and microwave unit to dry okara and it was reported that moisture content was reduced to as much as 95% and 88 – 90%, respectively. Dried okara was reported to be composed of about 10-12% crude fat, 24-34% crude protein, 4% total ash, and considerable amounts of vitamins (Wickramarathna & Arampath 2003; Rinaldi et al. 2000). Dietary fiber (42.4 - 58.1%) is the major component of okara but it also contains considerable protein (15.2 - 33.4%) and fat (8.3 - 10.9%). The most abundant fatty acid is linoleic acid about 54.1% followed by oleic acid which is about 20.4% (Li et al. 2012).

Unfortunately, there is still a paucity of information regarding characterization of dried okara as possible food ingredient and its shelf life as a dried powder. The main aim of this study was to extend the shelf life of okara by applying a two-step drying process. Accelerated Shelf Life Testing was conducted to estimate the shelf life of dried okara at Philippine ambient conditions under vacuum or atmospheric packaging environment.

MATERIALS AND METHODS

Procurement of wet okara

Fresh wet okara samples were immediately collected after processing from Supplier 2 which was a small silken tofu (*taho*) processing plant in Quezon City, Philippines (Table 1). The wet okara was transported to the food laboratory within 1 h from procurement. The wet okara samples were analyzed within 1 – 2 h from procurement while the samples intended for the two-stage drying procedure were stored in a chest freezer (Haier BD-519H, Philippines) at -10° C to -16° C for around 7 days prior to drying.

Two-stage drying protocol of okara

The study applied a two-stage drying scheme for okara. An initial stage of dewatering followed by drying in a mechanical dryer was used. The study utilized a hand-turned vertical screw-type presser (maximum capacity 10 kg) that was manually operated. About 6 kg wet okara was loaded at all trials in the manual vertical screw-type presser (Almedah Food Machineries Corp., Philippines) for the dewatering step. The pressing process was repeated three times by rotating the vertical screw to liberate a pressing force towards the okara. After dewatering, the

Table 1. Industry profile of silken† and firm†† soybean curd companies generating okara as by-product in Phillipines.

Related Information	Soybean curd industries				
	1	2	3	4	5
Product	Silken	Silken	Firm	Silken	Silken
Location	Quezon City	Quezon City	Manila	Quezon City	Manila
Years in the business	3	18	25	5	12
No. of workers	5	3	4	3	3
Source of raw soybean	Canada; Davao, Philippines	Canada; Davao, Philippines	Canada; United States	Canada	Canada
Price of raw soybean (Php/kg) (US,$)	45 (0.97)	35-45 (0.76-0.97)	30-40 (0.65-0.86)	45 (0.97)	65 (1.40)
Daily average weight of silken and firm soybean curd produced (kg)	550	400	5	240	90
Raw soybean used per production (kg)	90	50	17	40	20
Daily average weight of accumulated okara (kg)	200	100	25	50-55	100
Retail price of okara (PhP/kg) (US $)	5.0 ($0.11)	15.0 ($0.32)	10.0 ($0.22)	10.0 ($0.22)	4.0 ($0.09)
Shelf-life of okara at room temperature (h)	8	7 - 12	8	8	2 - 5

†Silken soybean curd locally known as taho; ††Firm soybean curd locally known as tokwa; 1 USD ($)=46.243 Php as of August 13, 2015

okara sample was immediately analyzed within 1 – 2 h as described below. The pressed okara was stored in a chest freezer (-10° C to -16° C) for up to 2 days before drying in a mechanical dryer.

Thirty kilogram batches of pressed okara were dried at the Department of Science and Technology-Industrial Technology Development Institute (DOST-ITDI) in Bicutan, Taguig City, Philippines. Drying was conducted using a gas-fueled cabinet dryer with dimensions of 1.2 m (length) x 0.80 m (width) x 1.4 m (height), set and preheated at 60° C for 30 min. The pressed okara material was distributed and spread on stainless steel trays that were lined with cheesecloth (0.15 m^2). The pressed okara was spread with about 0.5 cm thickness and dried with dry bulb temperature maintained at 60 °C for 4.5 – 5.0 h to reach 5 – 8% moisture content. After drying, the okara samples were transported to the laboratory and stored in a chest freezer for 1-2 days prior to analyses. The physicochemical characterization, proximate composition, microbiological analyses, and sensory evaluation of wet, pressed, and dried okara samples were also determined.

Physicochemical characterization

The color, pH, and water activity (a_w) of okara samples were determined. The quantitative value of lightness (*L**), redness (*a**), and yellowness (*b**) of wet, pressed, and dried okara was determined using HunterLab's ColorFlex®EZ port forward dual-beam spectrophotometer (Hunter Associates Laboratory Inc, USA). The pH values were determined using the pH 700 Bench Meter (Eutech Instrument, Singapore). The samples were prepared using a 1:4 okara to distilled water ratio. A Novasina water activity meter Model ms1 Set aw (Novasina, Switzerland) was used to determine a_w of the okara samples.

Proximate composition

Three hundred grams each of wet, pressed, and dried okara were submitted to *Intertek* Laboratory Testing Service, Philippines for the proximate composition analyses. The analyses included the determination of crude protein by Kjeldahl method (N x 6.25), crude fat by Soxhlet extraction, moisture by oven drying at 105°C, ash by gravimetric method, carbohydrates by difference, and dietary fiber by enzymatic, gravimetric method. The methods used were based on AOAC Official Methods of Analysis (AOAC 2005). In addition, the phytic acid content of okara was determined using the K-Phyt 07/11 kit with a simple quantitative method developed by Megazyme International, Ireland (2011). Sample extraction was done using 2.5 g sample added with 0.66 M hydrochloric acid. Samples were neutralized and added with 28 corresponding reagents for the enzymatic de-phosphorylation reaction and colorimetric determination of phosphorus. Phytic acid content was reported as g/ 100g.

Microbiological analyses

The Total Plate Count (TPC), Yeast and Mold Count (YMC), and Total Coliform Count (TCC) of the wet, pressed, and dried okara samples were determined (USFDA 2001).

Lactic acid bacteria (LAB) count was also determined using the modified method from the Compendium of Methods for the Microbiological Examination of Foods (American Public Health Association 1992). Twenty five grams of each okara samples were blended with 225 mL of 0.1% (w/v) peptone water (HiMedia Laboratories Pvt. Ltd., Mumbai, India) and serially diluted up to 10^{-5} before pour plating onto the respective plates for TPC, YMC, and LAB. Total Plate Count was analyzed using Plate Count Agar (HiMedia, Mumbai, India) and inoculated plates were incubated at 35°–37° C for 48 h. Acidified Potato Dextrose Agar (HiMedia, Mumbai, India) was used for YMC and the plates were incubated at 27° C for 5 days. For the LAB, Mann Rogosa Sharpe Agar (MRSA) (Laboratorios Conda S.A, Pronadisa,Madrid, Spain) was used and pour plate method with overlay was utilized. The inoculated MRSA plates were incubated at 35°–37° C for 24 to 48 h. Plate counts were reported as mean log colony forming unit per gram (log cfu/g) ± standard deviation.

For TCC, three-tube design for the Most Probable Number (MPN) method using Lauryl Tryptose Broth (HiMedia, Mumbai, India) and Eosin-Methylene Blue (Laboratorios Conda S.A.,Pronadisa,Madrid, Spain) were used. Gas formation and turbidity in the observed tubes indicated presumptive coliforms. Negative tubes were re-incubated for 24 h and re-evaluated. Loopful from positive tubes were streak plated onto pre-solidified Eosin Methylene Blue (EMB) agar. Colonies with green metallic sheen were confirmed for coliforms. The TCC were reported as mean log MPN per gram (log MPN/g) ± standard deviation.

Sensory evaluation

Descriptive analysis was used to characterize okara samples. A panel of ten people (8 females and 2 males, 18 to 46 years old) were trained for determination of intensity rankings of the wet, pressed, and dried okara through Quantitative Descriptive Analysis (QDA) (Meilgaard et al. 2006). A modified lexicon based on N'Kouka et al. (2004) and Torres-Peñaranda et al. (1998) was created for each sensory attribute through panel agreement. The sensory evaluation of the samples was divided into three sessions. The first session was allotted to lexicon development wherein the panelists developed the terms by using associative or cognitive words to describe the samples. The second and third sessions involved the verification of the lexicons previously developed by the panelists wherein wet, pressed, and dried okara were presented and compared to the reference materials. A five-point scale was used for each test which included the definition of each characteristic to properly describe odor, texture, and color for all samples as well as taste for dried okara. The following descriptors were used for the scale: 1=no/none, 2=slightly, 3=moderately, 4=strongly, and 5=extremely.

Rancidity indices

The rancidity indices of dried okara were determined through analyses of Free Fatty Acid (FFA), Peroxide Value (PV), and 2-Thiobarbituric Acid Value (TBA). The extraction of oil for analyses was done using the method of Meyer & Terry (2008). A 1:2 ratio of dried okara to hexane (Univar, Ajax Finechem, Australia) was homogenized for 1 minute using a high-speed blender. Homogenized sample was then filtered using a Whatman (#140) filter paper under vacuum and the solvent was evaporated to obtain the oil.

FFA. The FFA was determined using the modified AOCS Official Method Ca 5a-40 of Rukunudin et al. (2008). A 0.7 g of dried okara oil sample was diluted in 7.5 mL neutralized hot ethyl alcohol (~60°C) and titrated with 0.028 M sodium hydroxide (NaOH). The values were computed using the equation below:

$$\text{FFA} = \frac{C \, x \, D \text{ x } 28.2}{E} \qquad \text{(Equation 1)}$$

where C is the volume (mL) of NaOH solution used for the titration of sample, D is the concentration (normality) of NaOH and E is sample weight (g). FFA was expressed as % oleic acid.

PV. The PV was determined according to the modified AOCS Official Method Cd 8-53 of Crowe &White (2001). 0.5 g of dried okara oil sample was briefly dissolved in 30 mL of chloroform and acetic acid (2:3; v:v) solution. The PV of oil was analyzed by iodometric titration with 0.001 N $Na_2S_2O_3$ solution. The PV was calculated using the following equation:

$$\text{PV} = \frac{(F - G) \, x \, H \, x \, 1000}{I} \qquad \text{(Equation 2)}$$

where F is the volume (mL) used for titration of sample, G is the volume (mL) used for titration of blank, H is the concentration (normality) of the titrating solution and I is sample weight (g). Peroxide value was reported as meq/kg oil sample.

TBA. The TBA was determined following the AOCS Cd 19-90 method (2009), using 0.2 g dried okara oil sample dissolved in 1-butanol and 2-thiobarbituric acid. The TBA was measured by reading the absorbance of the sample solution and a blank at 530 nm. The TBA value was calculated using the equation below:

$$\text{TBA Value} = \frac{50 \, x \, (A - B)}{M} \qquad \text{(Equation 3)}$$

where A is the absorbance reading of the sample solution, B is the absorbance of the reagent blank and M is the weight (mg) of the test portion. The basis of the TBA method is the reaction of malonaldehyde (MDA) with TBA at low pH and high temperature to form a colored complex

with an absorption maximum at 532 − 535 nm that can be measured by visible absorption spectrophotometry (Sodergren 2000). The TBA value was expressed as mg MDA equivalent/kg oil sample

Shelf life study of dried okara

The Accelerated Shelf Life Testing (ASLT) (Fu & Labuza 1997) of dried okara was determined using two different packaging materials: (1) laminated PET/FOIL/PE vacuum pouches (width: 180 mm, length: 225 mm, gusset: 92 mm and thickness: 119 μm, MGM Food Commodities Corporation, Mandaluyong City, Philippines) under vacuum, and (2) Kraft bag with PE lining (width: 210 mm, length: 250 mm, gusset: 126 mm and thickness: 300 μm for kraft paper and 60 μm for PET lining, Geppco Paper Supply, Binondo, Manila, Philippines) at atmospheric pressure. Shelf life estimation of dried okara was done at accelerated temperatures of 35, 45, and 55° C with a target shelf life of 12 months at 30 °C (Fu & Labuza 1997). Shelf life was calculated using the equation of the line obtained by plotting the log of dried okara shelf life (in days) with respect to the inverse of the storage temperature (in Kelvin degrees) through data extrapolation (Fu & Labuza 1997). Separate graphs were created for kraft bag with PE lining and laminated PET/FOIL/PE packaging materials. Thus, 2 different equations were obtained and these were used to calculate the estimated shelf life given the target temperature of 30 °C. A Q_{10} value of 2.5 was used to compute for the sampling time and frequency using the equation below (OTA1979):

$$Q_{10}^{\Delta/10} = ts1/ts2 \qquad \text{(Equation 4)}$$

where, Q_{10} = temperature quotient; accelerating factor

ts1 = shelf life at lower temperature

ts2 = shelf life at higher temperature

Δ = temperature difference between lower and higher temperature

The sampling frequency at each storage temperature was calculated based on the following equation:

$$f2 = f1Q_{10}^{\Delta/10} \qquad \text{(Equation 5)}$$

where, f1 = time in between tests at the highest temperature T1

f2 = time in between tests at any temperature T2

As a quality control during accelerated shelf life testing the physicochemical properties, proximate composition, and sensory characteristics of dried okara were evaluated. Sensory characteristics monitored were color, odor (rancid) and texture (caking). Caking was defined as the agglomeration of powder particles into a coherent solid bulk (Calvert et al. 2013). Caking of dried okara samples was further considered as lumping together of smaller okara granules forming a larger unit. Sampling and analysis of dried okara was conducted until an unacceptable parameter was reached for each tested storage condition.

Statistical analyses

The results from analyses were expressed as mean values of at least triplicate determinations ± standard deviations. Data from sensory panel were means of n=10± standard deviations. Mean differences were analyzed using Analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) were performed using SPSS Statistics 19.0 Software (2009). An independent-sample t-test was done to compare the sensory characteristics of wet and pressed okara. Data were analyzed at 5% level of significance.

RESULTS AND DISCUSSION

Main commercial producers of silken (*taho*) and firm (*tokwa*) soybean curds in the Philippines that generate okara as by-product were identified as sources of wet okara used in the present study (Table 1). The industries were categorized as part of micro-industries defined by the Philippine Department of Trade and Industry (2008) as those having 1 – 9 employees with asset size of up to Php3,000,000 ($64,949). The okara-generating industries in this study were located in the National Capital Region, operated by a maximum of 5 workers and have been in the business for 3 – 25 years. Considering the amount of soybean used during soybean curd production, these micro-industries can produce up to 200 kg of accumulated wet okara on an average daily basis. The generated okara is normally stored in a covered large plastic drum container and stored at ambient temperature at around 28±2 °C. However, the wet okara is prone to putrefaction and it spoils in less than 12 h in this storage condition. Okara is immediately collected from the production area within 8 – 12 h by end users including farmers and some micro-scale food business. The wet okara by-product is sold for around 4 to 15Php/kg ($0.09 - $0.32/kg) based on information gathered from the soybean curd producers.

Characterization of wet, pressed and dried okara

Results of physicochemical, characterization, proximate composition profiles and microbiological quality of wet, pressed, and dried okara are summarized in Table 2. In general, the properties of wet okara were not significantly different from pressed okara at 5% level of significance, except for the following parameters: lower yellowness (*b*-value), decrease in moisture, and increase in dietary fiber, ash content and total plate count.

There were, however, significant changes in the physicochemical, microbiological characteristics,

proximate composition, and, sensory profiles of dried okara (Table 2). Dried okara was found darker, tending to be more reddish and yellowish in color than wet and pressed okara samples based on the *L, a,* and *b* color components, respectively. The observed color changes after drying may be due to Maillard reaction (Krokida et al. 2001) and caramelization with heating (Benjakul et al. 2005). The a_w and pH decreased in the dried okara while the phytic acid content increased after drying. Okara contains phytic acid as a major phosphorus storage compound (Zhou & Erdman 2009). The established phytic content of wet, pressed, and dried okara were still within reported phytate levels of 0 – 1.9 g/100 g in commonly consumed soybean and cereal-based foods in China (Ma et al. 2005).

Table 2. Physicochemical, microbiological, and proximate composition of wet, pressed, and dried okara.

Parameters	Wet Okara	Pressed Okara	Dried Okara
Physicochemical *Color*			
*L**	76.25±3.62^{ab}	80.29±4.93^{a}	70.68±2.77^{b}
*a**	2.49±0.34^{b}	2.11±0.57^{b}	5.80±0.18^{a}
*b**	20.88±1.54^{b}	17.69±1.60^{c}	27.92±0.59^{a}
a_w	0.896±0.020^{a}	0.908±0.007^{a}	0.327±0.043^{b}
pH	6.68±0.04^{a}	6.65±0.21^{a}	5.17±0.11^{b}
Proximate composition (%)			
Moisture	85.72±2.16^{a}	73.79±2.26^{b}	4.87±0.76^{c}
Protein	3.68±0.23^{b}	4.91±0.37^{b}	27.22±2.48^{a}
Fat	0.28±0.25^{b}	0.19±0.16^{b}	10.97±1.10^{a}
Total carbohydrate††	9.59±2.23^{c}	20.09±2.14^{b}	54.06±3.14^{a}
Dietary Fiber	5.02±3.86^{b}	12.04±8.64^{b}	56.92±4.20^{a}
Ash	0.66±0.09^{c}	1.02±0.11^{b}	2.89±0.13^{a}
Phytic acid (g/100g)	0.200±0.151^{b}	0.195±0.093^{b}	0.630±0.046^{a}
Microbiological			
Total Plate Count (log cfu/g)	3.83±1.12^{b}	6.09±1.26^{a}	7.38±0.06^{a}
Yeast & Mold Count (log cfu/g)	2.62±0.07^{b}	3.42±1.06^{b}	4.98±0.84^{a}
Lactic Acid Bacteria (log cfu/g)	4.16±1.36^{b}	5.67±1.26^{b}	7.66±0.67^{a}
Total Coliform Count (log MPN/g	1.59±0.25^{a}	1.76±0.61^{a}	1.86±0.32^{a}

^{a,b,c}Mean value ± standard deviation followed by the same letter within the same row are not significantly different at 5% significance level
††By difference (computation)
cfu = colony forming units
MPN = Most probable number

There was a significant change in proximate composition of dried okara at 5% significance level due to a decrease in moisture content (Table 2). Raw soybean seeds and full-fat soy flour contain around 9.30% and 9.60% dietary fiber, respectively (U.S. Department of Agriculture (USDA) 2013). Compared to raw soybean seed and soy flour, dried okara has higher dietary fiber content. However, the protein and fat content of dried okara was lower compared to the products mentioned (USDA 2013). The okara samples used in the present study were by-product of soybean curd processing from which soluble protein, fat, and other nutrients were deliberately extracted to produce *taho* (silken tofu) and *tokwa* (firm tofu). Upon separation of okara from the liquid portion of the commercial soybean-based products, water-soluble nutrients remain in the liquid portion while the insoluble fiber solids are separated. The established dietary fiber (56%) content of dried okara in this present study was comparable to the reported dietary fiber (50%) content of a commercially available okara (SunOpta 2007). Several studies have also identified the composition of dried okara. According to Li et al. (2012), dietary fiber (42.4 - 58.1%) is the major component of okara but it also contains considerable protein (15.2 - 33.4%) and fat (8.3 - 10.9%) and the most abundant fatty acid is linoleic acid about 54.1% followed by oleic acid which is about 20.4%. Other studies indicated that dried okara is composed of about 10-12% crude fat, 24-34% crude protein, 4% total ash, and considerable amounts of vitamins (Wickramarathna & Arampath, 2003; Rinaldi et al., 2000).

Microbial quality indicators YMC, LAB count, and TPC of dried okara were recorded to be about 5 – 7 log unit cfu/g while TCC remained less than 2 log MPN/g (Table 2). The TPC of dried okara was higher than the previously reported counts of 4.50 and 4.63 log cfu/mL for vacuum tray and microwave dried okara, respectively (Sengupta et al. 2012). However, the established YMC was lower than the reported value of 7.61 log cfu/mLfor both okara drying procedures (Sengupta et al. 2012). The variations in obtained microbial counts may be due to the differences in the initial microbial charge and also to handling conditions of okara sources as a by-product and the different drying protocols applied.

Sensory evaluation of wet, pressed and dried okara

There was a significant difference in the degree of wetness of wet okara (4.40±0.52) and pressed okara (2.92±0.32) as shown in Table 3 . The malty odor was no longer detected but the strong beany odor was still present after pressing of okara. In addition, wet okara color was determined to be cream to off-white in color after pressing with corresponding higher *L** values. In terms of texture, both wet and pressed okara were moderately gritty. Table 4 presents the results of the sensory evaluation of dried okara. After the drying process, the okara became slightly crumbly and moderately granular, flaky, grainy, and hard.

Table 3. Descriptive sensory evaluation of wet and pressed *Okara.*

Parameter	*Wet Okara*		*Pressed Okara*	
	Intensity Rating (1-5)	**Reference**	**Intensity Rating (1-5)**	**Reference**
***Odor*†**				
Beany	4.10±0.99[a]	60% aqueous solution of silken soybean curd (Quezon City, Philippines)	3.70±0.95[a]	60% aqueous solution of silken soybean curd (Quezon City, Philippines)
Vanilla	1.70±0.67[a]	0.1% vanilla solution (McCormick Vanilla Flavor, McCormick, Philippines)	1.50±0.53[a]	0.1% vanilla solution (McCormick Vanilla Flavor, McCormick, Philippines)
Milky	1.70±0.82[a]	2% milk solution (Nestle Bear Brand Powdered Milk Drink, Nestle, Philippines)	1.60±0.70[a]	2% milk solution (Nestle Bear Brand Powdered Milk Drink, Nestle, Philippines)
Malty	1.50±0.71[a]	1% malt beverage solution (Handyware Malt Beverage, Philippines)	1.40±0.52[a]	Distilled water (SM Bonus Distilled Water, Philippines)
Oily	1.50±0.97[a]	20% soya oil at 55 °C for 6 days + 80% fresh soya oil (UFC Golden Fiesta Soya Oil, Nutriasia, Philippines)	1.60±1.07[a]	20% soya oil at 55 °C for 6 days + 80% fresh soya oil (UFC Golden Fiesta Soya Oil, Nutriasia, Philippines)
***Texture*†**				
Grittiness	2.70±1.34[a]	355µm locally available pulverized rice bran (Quezon City, Philippines)	3.30±0.82[a]	355µm locally available pulverized rice bran (Quezon City, Philippines)
Wetness	4.40±0.52[a]	Dessicated coconut hydrated with water at 1:3 hydration ratio (Ideal Finest Quality Dessicated Coconut, Philippines)	2.92±0.32[b]	Dessicated coconut hydrated with water at 1:3 hydration ratio (Ideal Finest Quality Dessicated Coconut, Philippines)
***Color*††**				
	2.85±0.88[a]	Condensed milk (Carnation Condensed Milk, Philippines)	2.25±0.42[a]	Liquid milk drink (Nestle Bear Brand Sterilized Milk, Nestle, Philippines) (*for pressed okara*)

† Intensity descriptors: 1=none, 2=slightly, 3=moderately, 4=strongly, 5=extremely
†† Intensity descriptors: 1=white, 2=off white, 3=cream, 4=yellow, 5=tan
[a,b]Mean value of n = 10 ± standard deviation followed by the same letter within the same row are not significantly different at 5% significance level

Beany odor, which normally limits acceptability of most soybean products, was reduced after drying relative to wet and pressed okara. The dried product has no strong odors and tastes which makes it a good food ingredient that will blend well with other components of a food formulation. Dried okara color was described as yellowish cream which was slightly darker than the color perceived in wet and pressed okara. The color of dried okara was not very distinct from raw okara thus it can be incorporated in compounded food formulations with minimal alteration to the product appearance. Dried okara may also be a good food extender because of its protein, fat, and dietary fiber content.

Accelerated shelf life test of dried okara

The earliest detection of rancid odor through sensory evaluation was observed to be the first indicator of product deterioration, thus it was used as the basis of end of ASLT of dried okara (Fu & Labuza 1997). Figure 1 shows the rancid odor detection in dried okara placed in two different packaging materials and stored at three storage temperatures 35, 45, and 55º C. Vacuum environment and laminated PET/FOIL/PE bags were found to be a good packaging combination for dried okara because the shelf life of the powder was extended longer compared to atmospheric environment and kraft bags with PE lining. Properties of dried okara were monitored during ASLT.

Rancidity indices

Okara contains a large quantity of fat which makes it susceptible to hydrolysis and oxidation leading to rancidity (Aguado 2010). Dried okara in the study was established to have around 11% crude fat. The rancidity indices of the oil extracted from dried okara are shown in Figure 2. The FFA, PV, and TBA showed that hydrolysis and oxidation

Table 4. Descriptive sensory evaluation of dried *Okara.*

Parameters	Reference materials		
	Descriptor	Intensity Rating (1-5)	Details
Odor†			
Beany	moderately	2.79±1.07	30% tofu + 70% distilled water (Emperor's Tofu, Miracle Soybean Food International Inc.,Philippines)
sweet	slightly	2.21±0.91	25% honey +75% distilled water (CEMS Pure Honey, Philippines)
burnt	none	1.40±0.50	distilled water (SM Bonus Distilled water, Philippines)
nutty	slightly	2.43±1.51	1.5% peanut + 98.5% distilled water (Eric Crunchylicious Sung song Peanut, Philippines)
oily	slightly	2.14±0.90	2.5% soya oil at 55 ºC for 14 days + 97.5% fresh soya oil (UFC Golden Fiesta Soya Oil, Nutriasia Philippines)
Taste†			
Sweet	slightly	1.58±0.53	1% sugar solution (Victoria Refined Sugar, Philippines)
salty	none	1.43±0.53	distilled water
bitter	slightly	2.00±0.58	0.05% coffee solution (Great Taste Coffee Granules, URC, Philippines)
beany	moderately	3.14±0.38	50% *taho* + 50% distilled water (Locally available taho)
milky	slightly	1.86±0.70	25% soymilk + 75% distilled water (Vitamilk Soymilk, Greenspot Co.Ltd.,Thailand)
nutty	slightly	2.43±0.98	1.5% peanut + 98.5% distilled water (Eric Crunchylicious Sung Song peanut, Philippines)
oily	near slightly	1.57±0.53	2.5% soya oil at 55 ºC for 14 days + 97.5% fresh soya oil (UFC Golden Fiesta Soya Oil, Nutriasia Philippines)
Texture†			
crumbly	slightly	2.29±0.49	*polvoron* (Goldilocks, Philippines)
flaky	moderately	2.86±1.46	Oatmeal (Golden Oats, Golden Nutritious Food Corp., Philippines)
grainy	moderately	3.20±1.25	Corn grits (Variety 6 White Corn, Institute of Plant Breeding, UP Los Banos, Philippines)
granular	moderately	3.14±1.97	Coffee Granules (Great Taste,URC, Philippines)
hardness	moderately hard	3.29±0.76	Cornick (Captain Bawang Cornick, Philippines)
Color††	yellowish cream	2.86±0.38	Pantone 7401U

† Intensity descriptors: 1=none, 2=slightly, 3=moderately, 4=strongly, 5=extremely
†† Intensity descriptors: 1=white, 2=off white, 3=cream, 4=yellow, 5=tan
Mean value of n = 10 ± standard deviation

of the dried okara oil were still proceeding during storage. Free fatty acids which represent the hydrolysis of fats by lipases, metal ions, and high temperatures (Gulla & Waghray 2011) generally increased with storage. Crude soybean oil can contain up to 0.7% FFAs (Choe & Min 2006) and these levels can increase further by hydrolysis of oils during processing or storage (Yoshida et al. 1992). Legislative FFA limits for used oils were established in various countries: 2% in Germany and 2.5% in Belgium and Austria (Dobarganes & Marquez-Ruiz 1998). Similarly, PV, which reflects the amount of hydroperoxides as primary lipid oxidation products (Saldaña & Martínez-Monteagudo 2013), continually increased until it reached a peak then started decreasing. Good quality soybean oil has a PV of ≤ 2 meq/kg oil while PV of < 5 meq/kg oil was set for acceptable crude soybean oil (Debruyne 2004). Brazilian legislation has approved a maximum limit of 10 meq/kg for PV of commercialized soybean crude oil (Alencar et al. 2006). A study by Narayan et al. (1988) showed increasing PV for crude oil extracted from soybeans stored at various temperatures. Mean PVs up to 98 meq/kg oil was obtained for soybean stored for 108 months. For this study, the lipase and lipoxidase enzymes in the okara might have not been totally inactivated during silken soybean curd processing where the okara material of the study was obtained, thus contributing to the rancidity of the okara that was used. On the other hand, the TBA values of dried okara were within the acceptable value for food which is less than 5.0 mg of malonaldehyde/kg oil sample (Wachiraphansakul & Devahastin 2005). The

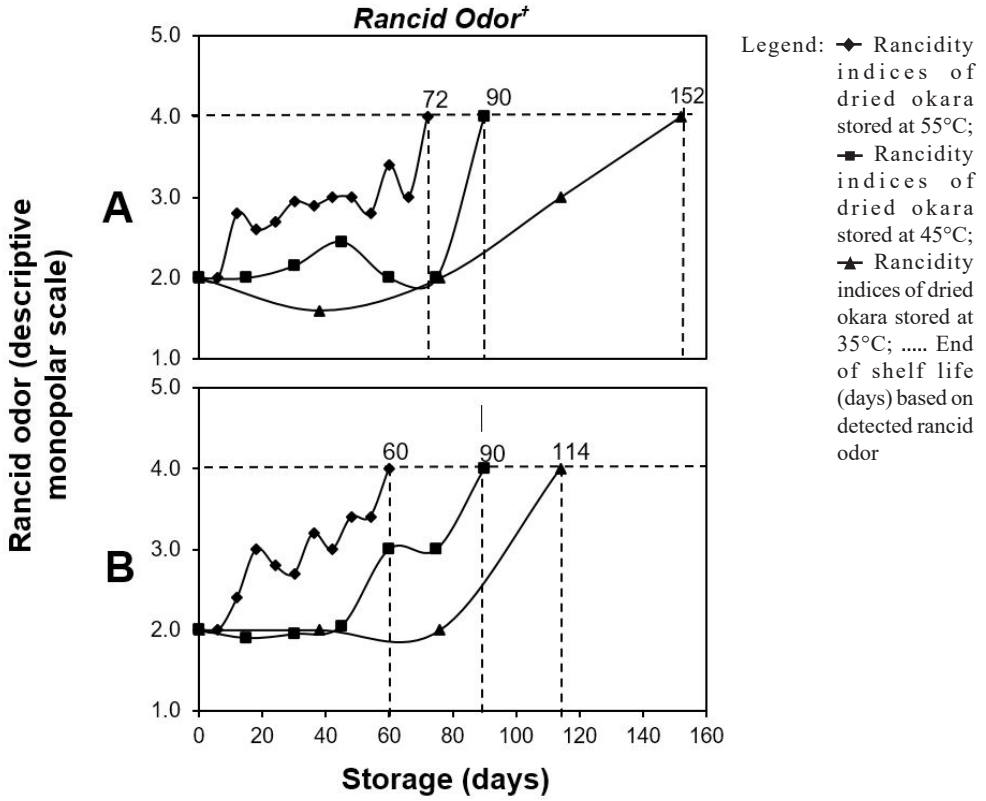

Figure 1. End of dried okara shelf life packed in (**A**) laminated PET/FOIL/PE (119 µm) and (**B**) kraft bag with PE lining (360 µm) based on rancid odor.
† Rancid Odor: 1=none, 2=slightly oily, 3=moderately oily, 4=detectable rancid odor, 5=strong rancid odo

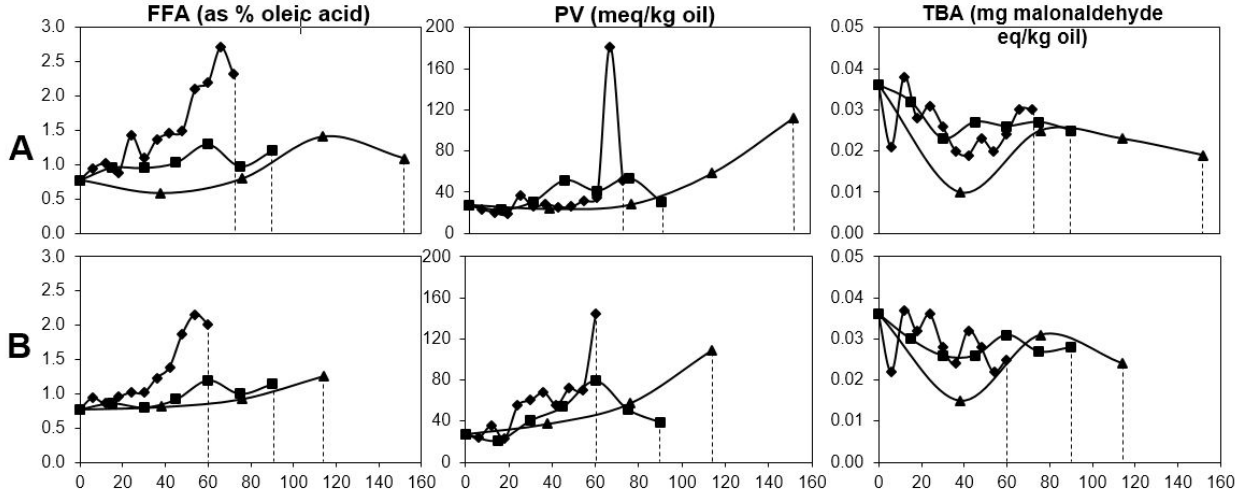

Figure 2. Rancidity indices of dried okara packed in (**A**) laminated PET/FOIL/PE (119µm) and (**B**) kraft bag with PE lining (360 µm) during shelf life monitoring.

Table 5. Quality of dried Okara within estimated shelf life during accelerated shelf life test.

Parameter	Vacuum-packed in Laminated PET/FOIL/ PE (119 µm)††	Atmospheric environment in Kraft bag w/ PE lining (360 µm)††
Sensory Characteristics (1)		
Color	cream – light brown	cream – light brown
Odor (rancid)	slightly oily – detectable rancid odor	slightly oily – detectable rancid odor
Texture (caking)	none - none	none - none
Physicochemical Properties (2)		
Color		
*L**	68.73 – 78.25	71.60 - 78.70
*a**	4.58 – 9.46	4.05 - 7.09
*b**	24.51 – 35.52	23.70 - 31.10
a_w	0.33 – 0.49	0.17 - 0.49
pH	5.17 – 5.35	4.53 - 5.29
Proximate Composition (%) (2)		
Moisture	6.67 – 6.84	3.58 - 6.90
Protein	21.84 – 30.10	21.63 - 32.24
Fat	6.65 – 11.14	5.80 - 7.69
Carbohydrates†††	49.09 – 61.56	53.62 - 62.84
Dietary Fiber	44.93 – 56.92	46.05 - 55.87
Phytic acid	0.06 - 0.65	0.39 - 0.65
Ash	2.89 – 3.63	3.32 - 3.48
Microbiological Analyses		
TPC, log cfu/g	≤ 4.70	≤ 3.37
YMC, log cfu/g	≤ 3.39	≤ 3.39
Total Lactic Acid Bacteria, log cfu/g	≤ 5.10	≤ 3.39
Total Coliform Count, log MPN/g	≤ 2.36	≤ 1.86

† Based on end of shelf life at accelerated storage temperature: 35 °C, 45 °C, and 55 °C
†† End of shelf life in days: 152, 90, and 72 in vacuum-packed laminated PET/FOIL/PE
End of shelf life in days: 114, 90, and 60 in atmospheric packaging kraft bag with PE lining
(1) Mean values of n=10 determinations; (2) Mean values of triplicate determinations
††† By difference (computation)
TPC = Total Plate Count (BAM, 2001)
YMC = Yeast and Mould Count (BAM, 2001)
Total Lactic Acid Bacteria (American Public Health Association)
cfu = colony forming units

TBA estimates the malonaldehyde formed as secondary oxidation products (USFDA 2001).

Influence of packaging on shelf life of dried okara

Based on the rancid odor from descriptive monopolar scale and rancidity indices of dried okara (Figures 1 and 2), the vacuum environment and laminated PET/FOIL/PE (119 µm) were more effective in extending its shelf life, despite the possible initiation of oxidation by metal ions from the packaging material (Frega et al. 1999; Vahcic & Hruskar 1999). The rancid odor was detected earlier on dried okara packed in atmospheric environment kraft bag with PE lining, most probably due to its more porous nature inspite of its thickness. A thinner packaging made of PET/Aluminum foil/PE of around 71 µm thick is reported to already have zero water vapor transfer rate (WVTR, g/ m^2 day at 23° C, 75% RH) (Lange & Wyser 2003). Thus, it can be expected that a similar packaging material with a thickness of 119 µm served as a good barrier. On the other hand, kraft paper (approximately 118 µm thick, nearly 3-times thinner than that used in this study) was reported to have WVTR of 194.82 g/m^2 h at 38° C (Larotonda et al.2003).

Additional quality characteristics of dried okara including sensory evaluation, physicochemical properties and proximate composition within estimated shelf life during

ASLT are summarized in Table 5. The data presented were based on results obtained from analyses of dried okara packed under vacuum in laminated PET/FOIL/PE bags.

Sensory evaluation of dried okara

During the ASLT, it was observed that the initially cream color of dried okara changed to light brown. From having a slightly oily odor, dried okara eventually had a detectable rancid odor which marked the end of its estimated shelf life. Regarding texture, dried okara was granular in form but no powder caking was observed in the samples throughout the accelerated shelf life study. Caking involves aggregation of particles leading to reduction of product flowability (Calvert et al. 2013). Caking would result in formation of large lumps in dried okara which might compromise its quality and might also pose a problem in food processing equipment. Wakiyama et al. (1992) reported that heat treatment of granules containing oily materials show an effective anti-caking effect. Dried okara was established to contain relatively high crude fat content which might have also aided in preventing formation of large lumps.

Physicochemical properties of dried okara

Important physicochemical properties of dried okara including color, a_w, and pH (Velasco et al. 2003) during ASLT are also summarized in Table 5. Changes in color were more apparent in dried okara stored in laminated PET/FOIL/PE perhaps due to presence of metal ions in the packaging material. Metal ions can form complexes with

Table 5. Quality of dried Okara within estimated shelf life during accelerated shelf life test.

Parameter	Vacuum-packed in Laminated PET/FOIL/ PE (119 µm)††	Atmospheric environment in Kraft bag w/ PE lining (360 µm)††
Sensory Characteristics (1)		
Color	cream – light brown	cream – light brown
Odor (rancid)	slightly oily – detectable rancid odor	slightly oily – detectable rancid odor
Texture (caking)	none - none	none - none
Physicochemical Properties (2)		
Color		
*L**	68.73 – 78.25	71.60 - 78.70
*a**	4.58 – 9.46	4.05 - 7.09
*b**	24.51 – 35.52	23.70 - 31.10
a_w	0.33 – 0.49	0.17 - 0.49
pH	5.17 – 5.35	4.53 - 5.29
Proximate Composition (%) (2)		
Moisture	6.67 – 6.84	3.58 - 6.90
Protein	21.84 – 30.10	21.63 - 32.24
Fat	6.65 – 11.14	5.80 - 7.69
Carbohydrates†††	49.09 – 61.56	53.62 - 62.84
Dietary Fiber	44.93 – 56.92	46.05 - 55.87
Phytic acid	0.06 - 0.65	0.39 - 0.65
Ash	2.89 – 3.63	3.32 - 3.48
Microbiological Analyses		
TPC, log cfu/g	≤ 4.70	≤ 3.37
YMC, log cfu/g	≤ 3.39	≤ 3.39
Total Lactic Acid Bacteria, log cfu/g	≤ 5.10	≤ 3.39
Total Coliform Count, log MPN/g	≤ 2.36	≤ 1.86

† Based on end of shelf life at accelerated storage temperature: 35 °C, 45 °C, and 55 °C
†† End of shelf life in days: 152, 90, and 72 in vacuum-packed laminated PET/FOIL/PE
End of shelf life in days: 114, 90, and 60 in atmospheric packaging kraft bag with PE lining
(1) Mean values of n=10 determinations; (2) Mean values of triplicate determinations
††† By difference (computation)
TPC = Total Plate Count (BAM, 2001)
YMC = Yeast and Mould Count (BAM, 2001)
Total Lactic Acid Bacteria (American Public Health Association)
cfu = colony forming units

some Maillard reaction products and it has been reported that their presence affects the intensity of browning in lactose/glycine model solutions (Ramonaityte et al. 2009). On the other hand, changes in moisture content and a_w of dried okara were more evident in kraft bag with PE lining. The pH of dried okara was slightly acid (around 5). Kraft bag with PE lining was most likely less effective in preserving the dried okara over the storage period because of significant changes in the properties of product. Despite its thickness, kraft bag with PE lining may still have allowed exchange of water vapor, moisture, and oxygen with the storage environment because of its more porous nature thereby allowing further drying of the product during ASLT.

Proximate composition of dried okara.

Table 5 also shows the composition (%) of dried okara within its estimated shelf life. Dried okara has high crude protein, crude fat, and dietary fiber content. High protein and dietary fiber content is advantageous for dried okara because it increases the value as a possible food ingredient. It was reported that vacuum dried and microwave dried okara has lipid content of 15% and 12%, respectively (Sengupta et al. 2012) which are close to the established 11% crude fat content of dried okara in the present study. The carbohydrate content of dried okara as calculated by difference in this study was higher than the reported carbohydrate content of vacuum and microwave dried okara that were 33% and 31%, respectively (Sengupta et al. 2012). Grizotto & Aguirre (2011) reported carbohydrate content of 38 – 45% for okara that had undergone flash drying. On the other hand, dietary fiber, and ash content were less than or equal to 32, 57, and 4%, respectively.

Calculated shelf life of dried okara

End of shelf life for dried okara in vacuum packed laminated PET/FOIL/PE (119 μm) based on the detectable rancid odor under accelerated shelf life study were 72, 90, and 152 days at storage temperatures of 55° C, 45° C, and 35° C, respectively (Figure 1A). On the other hand, end of shelf life for dried okara packed in atmospheric environment kraft bag with PE lining (360 μm) under accelerated shelf life study were 60, 90, and 114 days at storage temperatures of 55° C, 45° C, and 35° C, respectively (Figure 1B). The method used in the study to calculate the shelf life of dried okara was Q_{10} approach. Figures 3A and B show the plots that were used to calculate the shelf life of dried okara packed either in vacuum laminated PET/FOIL/PE (119 μm) or in atmospheric environment kraft bag with PE lining (360 μm), respectively. The estimated shelf life at the target storage temperature of 30° C (ambient condition in the Philippines) for dried okara packed in atmospheric environment kraft bag (360 μm) and vacuum laminated PET/FOIL/PE (119 μm) were 140 days (4.66 months) and 178 days (5.93 months), respectively. Laminated PET/FOIL/PE with a vacuum environment was able to better extend the shelf life of dried okara from an initial shelf life of only 12 h for wet okara.

In summary, dried okara, with an extended shelf life of up to 6 months at 30º C and a high protein and dietary fiber content, shows good potential as food ingredient. Micro-scale silken and firm soybean curd producers can further process the by-product okara into a more stable form. Dried okara may be utilized as food ingredient to enhance protein and dietary fiber in various food formulations instead of limiting its usage as local feeds.

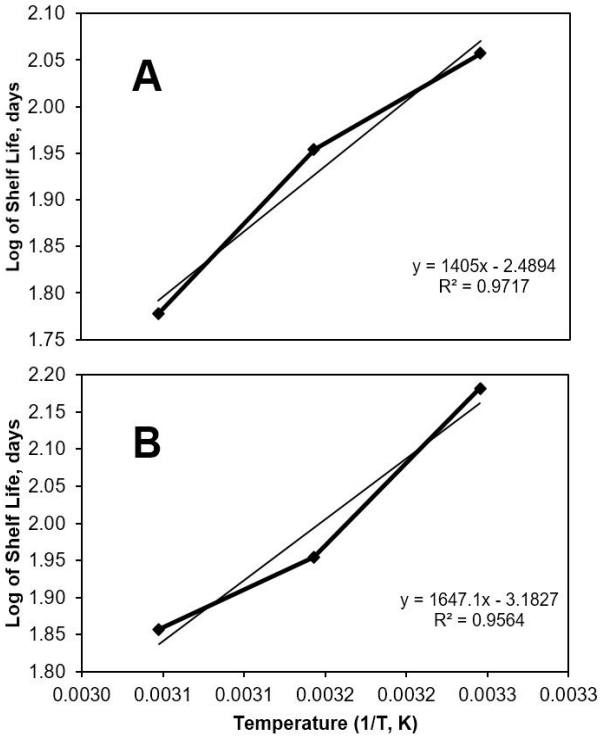

Figure 3. Plots of log of shelf life against storage temperature of dried okara in (**A**) atmospheric environment kraft bag with PE lining (360 μm) and (**B**) vacuum packed laminated PET/FOIL/PE (119 μm). *Shelf life of dried okara calculated using the equation from Figure 3A and 3B*.

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