

Applications of Liquid Smoke from Biomass on Food Products: A Review

Keryanti^{1,*} A R Permanasari¹ F Yulistiani¹ R P Sihombing¹ W Wibisono²

¹ Department of Chemical Engineering, Politeknik Negeri Bandung, Indonesia

² Department of Midwifery, STIKES Patria Husada Blitar, Indonesia

*Corresponding author. E-mail: keryanti@polban.ac.id

ABSTRACT

Liquid smoke or bio-oil is a renewable energy source that is the result of combustion or pyrolysis of raw materials containing hemicellulose, cellulose, and lignin that can be used for various purposes, both food and non-food applications. The content of anti-microbial and anti-oxidant compounds in liquid smoke encourages its use and application for food products, especially as a substitute for synthetic and conventional preservatives which has a negative impact on health and the environment. The aim of this article is to discuss the properties of liquid smoke from biomass waste pyrolysis and their application on food products. The review and analysis include the identification of the compounds contained in the liquid smoke resulting from the pyrolysis of biomass wastes and effect of the liquid smoke on characteristics of food products. From literature review and statistical analytic, the addition of liquid smoke was significantly increasing the hardness and gel strength of milkfish fish ball compared with control (without liquid smoke). The increase of liquid smoke concentration can increase textural characteristic and chemical characteristics such as protein content and fat content but decrease the water content.

Keywords: liquid smoke, anti-microbial, anti-oxidant, food preservation.

1. INTRODUCTION

Liquid smoke is compounds that evaporate simultaneously from the heated reactor through the pyrolysis (heat decomposition) and condense in the cooling system [1]. Liquid smoke is known by many other terms: bio-oil, biofuel oil, bio-crude oil, wood oil, wood liquid, wood vinegar, pyrolysis oil, pyrolytic tar, and pyrolytic acid [2]. Raw materials that are widely used to produce liquid smoke include various types of wood, oil palm nodes, coconut shells, husks, pulp, or sawdust, etc. Liquid smoke has main components, namely organic acids, phenol derivatives, and carbonyl [3].

In agriculture, liquid smoke is used to improve soil quality and neutralize soil acids, kill plant pests, control plant growth, repel insects, accelerate growth on roots, stems, tubers, leaves, flowers, and fruit [4]. Thus, liquid smoke is believed to be able to replace the function of chemical pesticides which are very harmful to health and the environment. Study of The effectiveness of liquid smoke made from palm kernel shells in inhibiting black pod disease (*Phytophthora palmivora*) in cacao fruit was conducted by [5]. In the plantation sector, liquid smoke can be used as a latex or rubber latex lump [6]. increases

because the rubber becomes whiter. Liquid smoke is also often used to preserve wood so that it lasts longer to decompose and avoid termites.

The presence of acid, phenol, and carbonyl compounds in liquid smoke has the potential to be used in the food industry. The content of phenol and acetic acid compounds in liquid smoke can inhibit the growth of bacteria such as *Pseudomonas fluorescense*, *Bacillus subtilis*, *Escherichia coli*, and *Staphylococcus aureus* [7]–[10]. Phenolic compounds can also act as antioxidants by stabilizing free radicals. Liquid smoke provides a specific aroma and better color quality to smoked products. Fish processing using liquid smoke has several advantages, such as easy to apply, product flavor is more uniform, can be used repeatedly, more efficient, can be applied to various types of food product, and minimize environmental pollution such as carcinogens and hazardous compounds i.e. tar and benzopyrene [1]. Smoke products that use liquid smoke are considered safe for health because they do not contain polyaromatic hydrocarbon (PAH) compounds [11].

Due to many advantages and applications of liquid smoke, the present review briefly discusses the role of liquid smoke in the preservation of food products. This

review will emphasize the use of liquid smoke which is produced using biomass wastes as raw material. The review and analysis include the identification of the compounds contained in the liquid smoke resulting from the pyrolysis of biomass wastes and effect of the liquid smoke application on characteristics of food products.

2. METHOD

A schematic diagram of the literature review procedure used in the present study is shown in Figure 1.

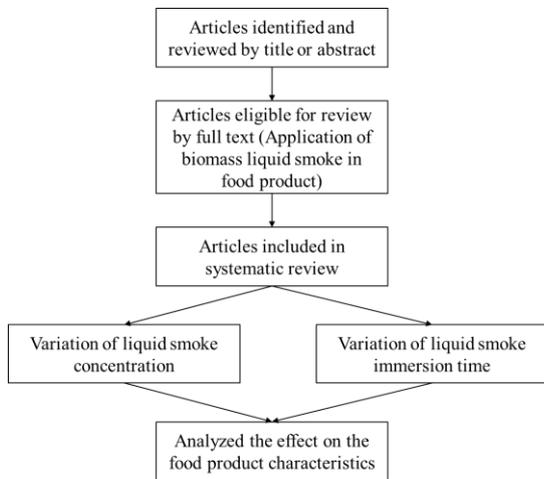


Figure 1 Schematic diagram of literature review process

The method used is a literature study by collecting data from several previous studies to determine the effect of concentration and immersion time of liquid smoke on the characteristics of smoked food products. Identifying the literature in similar subject became the first step of the systematic review. The literatures with an application of biomass waste liquid smoke is chosen to be analyzed.

Analysis of variance (ANOVA) was used to determine the significant of liquid smoke concentration, immersion time and interaction of both parameters to the characteristics of smoked food products.

3. RESULT AND DISCUSSION

3.1 Liquid Smoke Characteristic from Biomass Waste Pyrolysis

The quality of liquid smoke obtained from pyrolysis is strongly influenced by the type and particle size of raw material, the temperature used, water content of the raw materials and filtration and purification process. Different type of biomass wastes generates different levels of phenols, carbonyls, and organic acids upon pyrolysis which affect their antimicrobial and antioxidant properties (see Table 1). The quality of liquid smoke including acid and phenol levels will affect the effectiveness of the preservation process for food products.

Table 1. Chemical characteristic of liquid smokes from biomass waste

No.	Raw Material	pH	Acid content (%)	Phenol content (%)	Reference
1.	Coconut shell	4,10	2.52	6.70	[12]
2.	Young coconut fiber	2,60	5,2	0,66	[13]
3.	Nyamplung shell	NA	9,47	3,95	[14]
4.	Palm kernel shell	NA	1.2	0.31	[5]
5.	Oil palm empty fruit bunches	NA	0,454	5	[15]
6.	Corn cob	NA	4.48	2.55	[12]
7.	Oil palm shell	3.2	9.1	2.6	[16]
8.	Nutmeg beans shell	NA	0.15	0.69	[17]

Pyrolysis of hemicellulose produces furfural, furans, and their derivatives as well as carboxylic acids. Hemicellulose decomposition occurs at a temperature of 200-260°C [18]. Decomposition of cellulose occurs at 260-310°C [18]. The results of cellulose pyrolysis consist of acid and carbonyl compounds. The acid content in liquid smoke can affect taste, pH, shelf life, and anti-bacteria [19]. The acid compounds that exist include acetic, propionic, butyric and valeric acids. Carbonyl compounds derived from cellulose include acetaldehyde, glycol, and acrolein. Carbonyl compounds can react with proteins and form a brown color, which plays a role in the coloring and taste of the food product. This group of compounds has a unique caramel-like aroma.

Phenol is produced from lignin decomposition that occurs at 310-500°C [18]. Thermal decomposition of lignin will produce phenol and phenolic esters which has a role in providing aroma and exhibiting antioxidant activity to extend the shelf life of fumigation products. The aroma compounds are guaiacol (2-methoxy phenol), syringol (1,6-dimethoxy phenol) and their derivatives [20]. The difference in lignin content in liquid smoke raw material will affect the content of phenolic compounds in liquid smoke. The higher the lignin content, produces the higher the total liquid smoke phenol [21]. Phenol content produced from pyrolysis from a hardwood type raw material is high because it has higher lignin content than softwood [22].

3.2 Application of Biomass Liquid Smoke on Food Products

The main purpose of liquid smoke application in proteinaceous food products is not only to act as a colouring and flavouring agent, but also, to possess antibacterial and antioxidative properties that can increase shelf [23]. The application of liquid smoke can be used in fish, processed meats and fishes i.e. meatball, sausage, or chikuwa to replace the traditional

smoking process. It has also been used to add flavor to items such as cheese, tofu and even pet foods. It is viable for use on marinades, sauces, or brines and typically on processed meats such as bacon due to the concentration of smoke flavour. Table 2 shows some application of biomass waste liquid smoke on food products.

Table 2. Liquid Smoke Application on Food Products

No.	Raw material of LS	Food product	LS form/ Application	Concentration	Time of application	Optimum shelf life	Ref
1.	Corn cob and coconut shell	Stingray fish	Liquid/ Immersion	5%	15 min	3 days at room temperature	[24]
2.	Oil-palm shell	Pomfret fish	Liquid/ Immersion	8-10%	30 min	24 h at room temperature	[16]
3.	Coconut shell	Meatball and tofu	Liquid/ Immersion for tofu and mixing for meatball	0.5-2%	1-3 days into tofu soaking water	3 days at room temperatures	[25]
4.	Corn cob and coconut shell	Mackarel tuna	Liquid/ Immersion	1%	1-3 h	2 days at room temperature	[12]
5.	Coconut shell	Tuna fish	Encapsulated with chitosan and maltodextrin	2.5-10%	-	2 days at room temperature	[26]
6.	Coconut shell	Tilapia meat	Encapsulated/ Mixing	1-1.5%	-	6 days at 5°C	[27]
7.	Coconut shell	Nila fish	Liquid/ Immersion	5-17.5%	20 min	15 h at room temperature	[28]
8.	Coconut shell	Cakalang fish	Encapsulated	1%	-	18 h at room temperature	[29]
9.	Corn cob	Milkfish	Liquid/ Immersion	3%	-	NA	[30]
10.	Nutmeg shell	Yellow stripe scad fish	Liquid/ Immersion	10-20%	30-50 min	NA	[31]
11.	Coconut shell	Beef Se'i Bali	Liquid/ Immersion	2-10%	-	-	[32]
12.	Galam wood	Fish Cork	Biodegradable film	-	-	10 days at room temperature	[33]
13.	Corn cob	Milkfish meatball	Nanoencapsulated	1-5%	-	NA	[34]
14.	Palm kernel shell	Fishball	Liquid/ Immersion	1-3%	15 min	20 h at room temperature	[5]
15.	Lemongrass. Corn cob, coconut shell	Chikuwa tilapia	Liquid/ Added in the dough	2%	-	NA	[35]
16.	Rice husk	White tofu	Encapsulated/ Mixing	0.5-2%	-	2 days at room temperature	[9]
17.	Coconut shell	Yellow and White tofu	Liquid/ Immersion	-	-	3 days at room temperature	[36]

It can be seen in **Table 2** that most of the biomass liquid smoke is produced using raw materials in the form of coconut shell, corncobs, oil palm shell, and rice husks.

Several others are also produced from lemongrass, nutmeg shell and galam wood. Most of the liquid smoke used in food products is in liquid form, so it is applied by

soaking the food product for 15 minutes to 3 hours. The concentration of liquid smoke used varies from 0.5% to 20%.

Currently, liquid smoke has been developed in powdered form. The powder of liquid smoke is obtained from the process of encapsulation of liquid smoke with an encapsulation material such as chitosan, maltodextrin, and ca-alginate [9], [26], [27], [29], [34]. Liquid smoke in powdered form is easier in handling and application. Nanoencapsulation of bioactive compounds is efficient to increase the physical stability of active substances, protect them from interactions with food, and increase bioactivity due to subcellular size [26].

Martin [37] applies liquid smoke by spraying it on the frankfurters. An application of 2 or 3 ml refined liquid smoke at packaging resulted in at least a 1 log reduction of *Listeria monocytogenes* (Lm) within 12 h post packaging. A shelf-life study indicated that liquid smoke suppressed the growth of Lm for up to 130 days. Another study conducted by Salim [33] reported that liquid smoke can be applied in the form of biodegradable film. It able to maintain the quality of Gabus fish better on testing microbiological especially on the value of the TPC and coliform for storage 10 days at a temperature of ± 4 °C.

Liquid smoke that can be used for food product is usually Grade 1. Grade 1 liquid smoke has the best characteristics for consumers convenience and liking. It is very slightly yellowish and has the highest clarity compared to the other grades (Grade 2 and Grade 3) [10]. The difference between each liquid smoke grade is based on the extent of separation and purification stages. Several purification and filtration processes that are used to obtain food grade liquid smoke including filtration, distillation, redistillation (two stage distillation), and purified using the adsorbent zeolite or activated carbon [5], [10], [38].

3.3 Effects of Liquid Smoke on the Characteristics of Smoked Food Products

In the next section we will focus to discuss the effect of the concentration of liquid smoke and immersion time on the textural and chemical characteristics of smoked food products.

3.3.1. Effect of Liquid Smoke Concentration on The Food Textural Characteristic

Wijayanti et al [38] reported that the addition of liquid smoke gave significant effect on the textural characteristic such as hardness, deformation, and gel strength. The analytical result using ANOVA to determine the effect of liquid smoke concentration in liquid and encapsulated form to the hardness and gel strength value is shown in Table 3 and Table 4. Concentration of liquid smoke were variated at 0-5%.

Table 3. Analytical result of liquid smoke concentration effect to the hardness value by ANOVA

Source of variation	F	P-value	F crit	Ref
Filtered LS concentration	79.53	0.0001	5.99	[38]
Nano encapsulated LS concentration	107.8	0.0005	5.99	[34]
α		0.05		

Table 4. Analytical result of liquid smoke concentration effect to the gel strength value by ANOVA

Source of variation	F	P-value	F crit	Ref
Filtered LS concentration	31.58	0.0013	5.99	[38]
Nano encapsulated LS concentration	81.31	0.0001	5.99	[34]
α		0.05		

Addition of filtered liquid smoke was significantly increasing the hardness and gel strength but reducing deformation of milkfish fish ball compared with control (without liquid smoke). The increase of hardness and gel strength is probably caused by phenol content in liquid smoke that can interact with protein forming the complex bonds and crosslinking. But the hardness was decrease for liquid smoke concentration of 5% [39]. Balange and Benjakul [40] reported that the decrease of hardness in higher concentration might be associated with self-aggregation of phenolic compounds, causes the loss in capability of protein crosslinking. Leviyani et al [35] also resulted that the chikuwa tilapia dough mixed with coconut shell liquid smoke has the higher hardness (2600 gf) than control (without liquid smoke treatment) (2176 gf).

3.3.2. Effect of Liquid Smoke on The Food Chemical Characteristic

Addition of liquid smoke at different concentration also can affect the food chemical characteristic including water content (moisture), protein content, lipid/fat content and ash content. Usually the characteristic of products produced are compared to Indonesian National Standard (SNI) or the requirements for quality and food safety of food product by the National Standardization Agency (BSN) i.e. SNI 7266-2014 for fish ball, SNI 2725-2013 for smoked fish, SNI 01-3142-1998 for tofu.

Water Content

Swastawati et al [24] reported that application of 5% coconut shell liquid smoke can improve quality of stingray in moisture content from 73.78% (raw) into 61.47% (smoked). The result of milkfish moisture

content that smoked by 3% redistilled corncob liquid smoke and zeolite was 47.52% [27]. Overall, water content or moisture of smoked product by liquid smoke were in the range of Indonesian smoked fish standard SNI 2725-2013 (max. 60 %).

Wijayanti [38] reported that water content of milkfish meatball with filtered liquid smoke treatment at concentration 1-3% was 59.64-61.56% which are fulfilled the requirements of SNI: 7266-2014 on quality and safety of fish balls (max. 65%). The control of this treatment has higher moisture content, hence, not satisfying the SNI requirement. In the filtered liquid smoke treatment, the water content of milkfish meatball decreased with the increasing concentration. Statistical analysis by Swastawati [34] showed that the concentration of nano-capsulated liquid smoke had a significant effect on the moisture of milkfish meatballs ($P < 0.05$).

Immersion time also affect water content of smoked food product. Hardianto's research [12] resulted that the water content value of smoked mackerel tuna soaked in liquid smoke for a longer time is lower than for a short time. The average water content of smoked mackerel tuna which was treated with the addition of 1% corncob and coconut shell liquid smoke ranging from 69.32 - 72.42%. While the water content value of control mackerel tuna on the second day of storage was 74.63%.

Andiana [9] reported that storage time, the encapsulation product concentration and their interaction significantly affect the water content of white tofu. The results showed that water content decreases with increasing concentration of encapsulated liquid smoke and the overall water content in white tofu increased during the increasing storage time. Control product had the highest water content and the sharpest increase in water content, compared to addition of the encapsulated liquid smoke product at a concentration of 0.5-2%. But water content of each concentration variation was not significantly different ($P > 0.05$). It was because the difference value of the range is too small. The 2% of encapsulation product resulted in the smallest increase in water content compared to the other smaller concentration encapsulation products.

Protein Content

Hardianto's research [12] showed that mackerel tuna that had been soaked in 1% coconut shell liquid smoke for 2 hours had a higher protein content (21,2%) compared to the control (15,5%). At room temperature, that smoked mackerel tuna can last up to 2 days. Another experiment by Levayani [35] resulted that the protein content of chikuwa tilapia treated with lemongrass, coconut shell, and corncob liquid smoke (2%) were 14.37%, 15.51%, and 14.57% respectively. Those values were higher than protein content in control which was 11.9%.

The concentration of liquid smoke affected the protein content of milkfish meatball [38]. The highest protein content in milk fish meatballs was at highest liquid smoke concentration i.e. 5%. Fish balls added with 1% and 3% liquid smoke were not significantly different. All milkfish meatball treated with 1-5% nano-encapsulated liquid smoke from Swastawati [34] also had higher protein content than control. All treatments showed that protein content had met Indonesian national standards of at least 10%.

The analysis of variance by Andiana [9] showed that the storage time and the concentration of the encapsulated liquid smoke products had a significant effect on the protein content of white tofu ($P < 0.05$). Overall protein content of white tofu decreased during storage due to the activity of bacteria using nitrogen. The 0% concentration has the lowest protein content and the sharpest decrease in protein over time of storage compared to the addition of encapsulation products with a concentration of 0.5% - 2%.

Fat Content

Lipid content in the milkfish meatballs treated with filtered liquid smoke increased with the concentration of liquid smoke [38]. The highest lipid content was 0.95% at fishballs treated with filtered liquid smoke 5%, while lipid content of control was 0.6%. Swastawati [34] also gave similar result that the nano-encapsulated liquid smoke treatment showed the higher fat content than without treatment. The results of Dheko's research [32] showed that the use of coconut shell liquid smoke can increase the fat content of beef se'i. This increase in fat content is due to the presence of phenolic compounds which can inhibit negative chemical reactions in beef se'i fat treated with liquid smoke. Therefore, the fat content in beef se'i that were treated with liquid smoke was higher than those without liquid smoke. Salindeho's research [31] showed that the fat content in liquid smoked fish is also influenced by the duration of soaking the product with liquid smoke.

4. CONCLUSION

Various studies have been carried out aimed at the production of liquid smoke from biomass wastes. through different materials. From literature review and statistical analytic, the addition of liquid smoke was significantly increasing the hardness and gel strength of milkfish fish ball compared with control (without liquid smoke). The increasement of liquid smoke concentration can increase textural characteristic and chemical characteristics such as protein conten and fat content but decrease tha water content.

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