Philippine Journal of Science
150 (2): 391-396, April 2021
ISSN 0031 - 7683
Date Received: 27 Jul 2020

Okra (*Abelmoschus esculentus* L. Moench) Pod Gel as a Low-cost Alternative to Commercial Acoustic Gel

Mark M. Alipio*

College of Radiologic Technology, Iligan Medical Center College
Iligan City, Region X 9200 Philippines

Ultrasound is an essential diagnostic tool in medicine. However, a commercial acoustic gel is cost-prohibitive, especially in low-resource settings. In this study, okra (*Abelmoschus esculentus* L. Moench) pod gel was evaluated as a low-cost alternative to commercial acoustic gel by comparing the sonographic image quality, organoleptic characteristics, spreadability, pH, viscosity, and ease of use of commercial gel and formulated okra pod gel (OPG). Fresh okra pods were harvested from a local plant nursery. OPG was prepared by mixing okra pods with water and cooking the mixture on medium heat. OPG and commercial gel were physically evaluated and randomly swabbed to different surfaces of a human tissue-mimicking phantom to obtain sonographic images. Five experienced sonologists rated the sonographic images based on image quality parameters. OPG had optimal appearance, texture, homogeneity, and pH value. OPG had higher spreadability but lower viscosity compared to commercial acoustic gel. No significant difference was reported in the image quality parameters between the gels used. Acceptability of OPG in terms of ease of use was the same as that of commercial gel. However, the sonologists reported that compared to commercial gel, OPG did not evaporate easily during the sonographic procedure. Based on the evaluation, OPG is feasible as a low-cost alternative to commercial acoustic gel. Further clinical trials employing actual patients are recommended to increase the validity of the study results.

Keywords: low-resource setting, natural products, okra pod, ultrasound gel

INTRODUCTION

Ultrasound is a valuable tool in the imaging of soft-tissue organs in the body. In practice, an ultrasound machine's probe sends high-frequency waves towards the body organ, receives the reflected waves, and transforms them into information critical to diagnosis (Enriquez and Wu 2014). To aid the transmission of sound waves, a mucilaginous acoustic gel is placed on the skin surface (Abo 2014). Without this gel, the produced images would have poor quality and diagnostic information may be interpreted inaccurately (Bradley 2019). This gel is produced commercially by mixing propylene glycol, trolamine, EDTA (ethylenediaminetetraacetic acid), distilled water, and carbomer at an appropriate mix proportion set by the World Health Organization (Cabrelli *et al.* 2016). Despite its diagnostic value, the use of ultrasound is currently challenged especially in less-economically developed settings due to the unavailability and high cost of consumable ultrasound products, specifically acoustic gel (Binkowski *et al.* 2014; Salmon *et al.* 2015; Monti 2017).

Few published studies examined alternatives to commercial acoustic gel. Cornstarch, glucomannan powder, cassava

*Corresponding Author: markmalipio@gmail.com

flour, and olive oil were potential alternatives. However, these materials have low spreadability on the skin surface and require a tedious process of production, specifically in the monitoring of temperature to attain optimal consistency (Luewan *et al.* 2007; Binkowski *et al.* 2014; Aziz *et al.* 2018; Milton *et al.* 2018). In addition, physiochemical properties needed to assess gel consistency and improve acceptability by the performing healthcare professionals were not reported previously. In general, there is still a need to find practical alternatives to commercial acoustic gel.

Okra (*Abelmoschus esculentus* L. Moench) is one of the most widely known vegetable crops in tropical and sub-tropical countries, such as Taiwan, Thailand, and India (Singh *et al.* 2014). In the Philippines, it is considered a priority crop owing to its commercial and industrial potentials (Mina *et al.* 2015). Hence, local sources are abundant and accessible. Mucilage, a soluble and viscous dietary fiber and a primary feature of an ideal acoustic gel, could be extracted from the pods of okra and has an intrinsic viscosity value of about 30% when dissolved in water (Habtamu *et al.* 2015). With this, okra differs from other common vegetables in having high mucilage content (Gemede *et al.* 2018). Thus, it encompasses various food applications as a thickener, emulsifying agent, gelling agent, stabilizer, and whipping agent for plant-based adhesives (Tyagi *et al.* 2015; Farhana *et al.* 2017; Durazzo *et al.* 2019).

Using okra pods and water, which are both inexpensive and within easy reach, the study aimed to evaluate the potential of OPG as a low-cost alternative to commercial acoustic gel by comparing the sonographic image quality, organoleptic characteristics, spreadability, pH, and viscosity using OPG and commercial gel. Furthermore, the study evaluated the sonologists' subjective assessment of the gel's ease of use during the procedure.

MATERIALS AND METHODS

Collection of Materials

Fresh okra pods were harvested at the edible maturity stage from a local plant nursery in Davao City, Philippines. This nursery propagates and grows non-genetically modified plants in an organic method. The plants used were specified and verified by a botanist employed in a higher education institution in Davao City, Philippines.

Preparation of OPG

The method used in the preparation of acoustic gel was adapted and improved from previous studies (Binkowski *et al.* 2014; Alipio *et al.* 2019). After the removal of seeds, peduncles, and other unnecessary parts, the collected okra pods were washed with distilled water. The okra pods were weighed and 1 kg of the plant sample was collected. The pods were then mixed with 500 mL of water and the mixture was cooked on medium heat (162–189 ºC) by means of an electric stove. The mixture was thoroughly stirred for 20 min and transferred to a beaker of 1000 mL to allow it to cool for 10 min. The mixture was then filtered using a fine mesh strainer to remove pods and other debris. The OPG obtained was then placed in empty acoustic gel containers. AquaSonic 100 Sterile Ultrasound Transmission Gel (Parker Laboratories, Fairfield, New Jersey, USA) with a light green color has been used as a commercial gel.

Physical Evaluation of Acoustic Gels

Organoleptic characteristics. OPG and commercial gel were tested for color, homogeneity, immediate skin feel, physical appearance, and texture. Color and physical appearance were based on visual observation, while immediate skin feel was assessed by evaluating the greasiness, grittiness, and stiffness of the gels. Homogeneity and texture were determined by pressing the gels between the index finger and thumb and assessing the consistency of and presence of coarse particles in the gels.

Spreadability. A 1-g sample of each gel was placed between two glass plates (10 cm x 20 cm) that are horizontally mounted from each other. A 100-g weight board was placed on the upper glass plate to compress the sample. The spreadability of the gels was measured by calculating the spreading diameter after 1 min. Each gel was tested three times.

pH values. A 1-g sample of each gel was dispersed in 20 mL of deionized water, and a pH meter was used to measure the pH value of each gel. Measurements were repeated three times.

Viscosity. A Brookefield Viscometer with a cylinder spindle number 7 was utilized to measure the viscosity of the acoustic gels. The spindle was rotated at 0–100 rpm values at a temperature of 25 ºC, and viscosity was calculated in centiPoise (cP). Viscosity at 50 rpm value was considered. Measurements were done in triplicates.

Analysis of Sonographic Images

Ultrasound examinations were performed in a human tissue-mimicking phantom using a GE Healthcare Ultrasound Machine. The scanning protocols and techniques were adapted from those of Tempkin (2014). The phantom was positioned supine, and 10 mL of acoustic gels were randomly swabbed into the 15 different surfaces of the phantom.

A linear probe was then placed in the phantom's surface, and an ultrasound image was captured and saved. The scan was repeated three times per acoustic gel per surface of the phantom, resulting in 90 saved images (3 repetitions x 2 acoustic gels x 15 surfaces). An 80-kB size of information was allocated per image, and all of the ultrasound machine knobology were set the same for each scan.

Five experienced sonologists, with more than ten years of experience in the clinical practice, separately evaluated the images based on the four image quality parameters – namely, the level of acceptability, visibility of detail, amount of recorded detail, and distortion. Each image quality parameter was rated on a five-point Likert scale with "5" as "very high" and "1" as "very low." All of the selected evaluators obtained a board-certified license to practice sonology and attended a post-graduate ultrasound training program. The evaluators were blinded with the type of acoustic gel used in the image. The same laptop, screen, and room lighting were utilized during the conduct of image evaluation.

Subjective Assessment of Acoustic Gels

The sonologists' subjective assessment on the acceptability of gel in terms of ease of use was undergone through the completion of a three-question survey after each scan. Each question in the survey was rated on a five-point Likert scale with "5" as "strongly agree" and "1" as "strongly disagree." Several questions were adopted from those of Aziz and colleagues (2018).

Data Collection and Analysis

Descriptive statistics (mean and standard deviation) were used to describe the average value of the four image quality parameters, spreadability, pH, viscosity, and subjective assessment of the tested acoustic gels. The independent t-test was utilized to compare the acceptability and quality of images obtained using the tested acoustic gels. A p-value of less than 0.05 was considered significant.

RESULTS

Physical Evaluation of Acoustic Gels

OPG and commercial gel were characterized as light green, homogeneous, not greasy, not gritty, not stiff, and smooth (Table 1). OPG had higher spreadability, but lower viscosity compared to commercial acoustic gel (Table 2). The pH of both gels was slightly acidic. The spreadability, pH, and viscosity values were statistically different in both gels used ($p < 0.05$).

Table 1. Organoleptic characteristics of the acoustic gels.

Parameters	Commercial	OPG
Color	Light green	Light green
Homogeneity	Homogeneous	Homogeneous
Immediate skin feel	Not greasy, not gritty, not stiff	Not greasy, not gritty, not stiff
Physical appearance	Transparent	Transparent
Texture	Smooth	Smooth

Table 2. Spreadability, pH, and viscosity values of the acoustic gels (n = 9, results depicted as mean ± SD) and t-test.

Parameters	Commercial	OPG	p-value
Spreadability (mm)	20.07 ± 0.05	27.13 ± 0.09	< 0.001
pH	5.62 ± 0.01	4.60 ± 0.02	< 0.001
Viscosity (cP)	18651.00 ± 0.82	8812.00 ± 0.82	< 0.001

Analysis of Sonographic Images

The analysis of sonographic images indicated that OPG had a comparable level of acceptability, visibility of detail, amount of recorded detail, and distortion to that of commercial product (Table 3; Figure 1). The results also reported that the image quality parameters were statistically the same for both gels tested ($p > 0.05$).

Table 3. Image quality values of the sonograms scanned using the acoustic gels (n = 45, results depicted as mean ± SD) and t-test.

Image quality parameters	Commercial	OPG	p-value
Level of acceptability	3.96 ± 0.38	3.99 ± 0.37	0.70
Visibility of detail	4.03 ± 0.33	3.94 ± 0.35	0.25
Amount of recorded detail	3.96 ± 0.36	3.93 ± 0.41	0.70
Distortion	1.50 ± 0.19	1.53 ± 0.17	0.42

Subjective Assessment of Acoustic Gels

Most of the subjective assessment scores of the sonologists were similar in both OPG and commercial gel (Table 4). Acceptability of OPG in terms of ease of use was comparable to that of commercial gel. However, the sonologists reported that compared to commercial gel, OPG did not evaporate easily during the sonographic procedure.

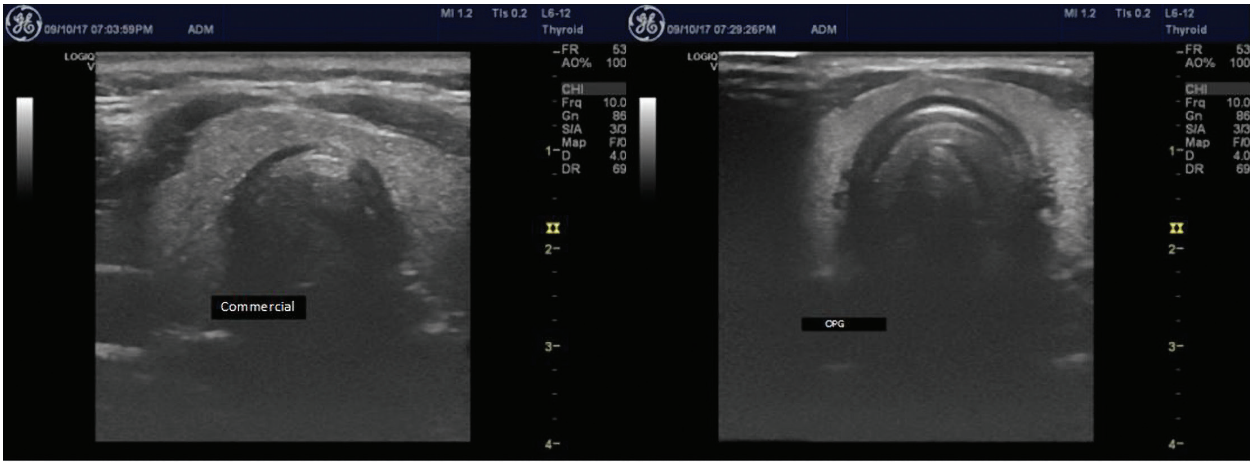

Figure 1. Human thyroid phantom imaged using commercial gel and OPG.

Table 4. Subjective assessment of acoustic gels (n = 45, results depicted as mean ± SD) and t-test.

Items	Commercial	OPG	*p*-value
1. The gel used in the scan was messy.	1.20 ± 0.45	1.40 ± 0.55	0.55
2. The gel used in the scan was easy to remove.	4.60 ± 0.55	4.40 ± 0.55	0.58
3. The gel did not evaporate easily during the scan.	1.80 ± 0.45	4.20 ± 0.84	< 0.001

DISCUSSION

OPG was formulated in this study from low-cost and highly accessible materials. The formulation used a simple heating method, and the obtained gel was physically evaluated on the basis of its organoleptic characteristics, spreadability, pH, viscosity, and ease of use. Five evaluators analyzed the sonographic images obtained after a series of ultrasound scans based on four parameters of image quality – namely, the level of acceptability, visibility of detail, amount of detail recorded, and distortion.

The physical analysis revealed that both OPG and commercial gels had an optimum appearance, texture, and homogeneity. The OPG had a light green color. In the study, the plant sample used contains water-storing tissues composed of simple parenchymal cells containing chlorophyll, giving OPG a light green color (Vernon and Seely 2014).

The spreadability and viscosity tests revealed that the OPG had a higher spreadability but lower viscosity compared to the commercial gel. The spreadability of the formulation is the ability to spread evenly on the surface of the skin (Andrade *et al.* 2014). Previous studies have reported that this parameter plays a significant role in the application of gel for medical purposes. However, in ultrasound examinations, the acoustic gel is not used as a therapeutic agent but is primarily used to enhance the transmission of sound waves from the probe to the organ of interest (Chaudhary and Verma 2014).

On the other hand, the viscosity of the formulation refers to its thickness due to internal friction. This parameter is one of the most important factors to consider when developing acoustic gel (Dimic-Misic *et al.* 2014). Highly viscous fluids contain molecules that are arranged close together compared to low viscosity fluids (Dimic-Misic *et al.* 2014). Sound waves travel faster in molecules that are packed together than in loosely packed molecules. Previous studies have shown that the mucilage substance found in the water-storing tissues of the okra pods accounted for the viscosity of the plant extract (Habtamu *et al.* 2015; Gemede *et al.* 2018).

Based on their pH values, both gels were slightly acidic. The pH of the formulation to be used should match the pH of the skin to avoid skin irritation and other reactions (Tamayol *et al.* 2016). The pH of the skin varies from 4–7 (Tamayol *et al.* 2016). The acoustic gels tested were optimal in terms of pH as the results matched the normal pH range of the skin. Previous gel alternatives have not addressed the issue of skin sensitivity of the produced gel (Luewan *et al.* 2007; Binkowski *et al.* 2014; Salmon *et al.* 2015; Monti 2017; Aziz *et al.* 2018; Milton *et al.* 2018; Alipio *et al.* 2019). This study offers significant novelty in that it first reports the pH of the tested alternative and considers this factor in the formulation to avoid skin allergies that could occur during any ultrasound examination.

The analysis of the image quality parameters showed that OPG was comparable to the commercial gel in terms of acceptability, visibility of detail, amount of detail recorded, and distortion. The level of acceptability refers to the adequacy of the image for diagnostic interpretation, while the visibility of detail refers to the clarity of the structure of the organ (Bushong 2013). The amount of detail recorded refers to the sharpness of the structures of the relevant anatomy, and the distortion refers to the degree of misrepresentation of the anatomy scanned in the image display (Bushong 2013). The levels of acceptability, visibility of detail, amount of detail recorded, and distortion were robust indicators of image quality in ultrasound practice. Similar to the previous report, the parameters of image quality were statistically identical between formulated and commercial acoustic gels (Binkowski *et al.* 2014). However, a previous study using *saluyot* (*Corchorus olitorius* L.) gel showed statistically higher visibility of detail and amount of recorded detail compared to commercial acoustic gel (Alipio *et al.* 2019). The differences in the results of previous research could be attributed to the number of evaluators who rated the image quality of the sonographic images. The two studies employed only one sonologist and did not mention the clinical experience or prior training received by the evaluator. The use of only one sonologist with no clinical expertise as an image evaluator could have yielded incorrect results and image quality interpretation, as the evaluator had no prior knowledge of sonographic images. In order to control possible variations in ratings, the present study recruited five sonologists with more than ten years of experience in clinical practice. In comparison to the previous studies, all sonologists were blinded by the type of ultrasound gel used during the assessment to avoid potential rating biases. In addition, the assessment was carried out in a separate room using the same laptop, screen, and room lighting to control possible external factors that might affect the rating. Using a highly controlled sonographic image evaluation, the SDs of the image quality parameters were less than 0.50, which represents the homogeneity of the responses of the sonologists. Future studies may consider including interrater analyses to control nature for the rater-dependence of the sonographic image assessment.

The OPG formulated could be a superior alternative to commercial acoustic gel for ultrasound examinations, especially in low-resource communities. The Philippines and other developing countries that are currently experiencing problems with the use of ultrasound and the availability of ultrasound gel could benefit from OPG. The tested sample is cheaper, readily available, and easy to produce compared to commercial acoustic gel and previous gel alternatives. Cornstarch, cassava, and olive oil-based gels – although cheap – have economic value in tropical countries and are widely used as food products (Luewan *et al.* 2007; Aziz *et al.* 2018; Milton *et al.* 2018). The production of these gels requires strict temperature controls in order to achieve optimum consistency. In the study, the okra pods were only subjected to simple heating and filtration methods and yield an image quality comparable to that of commercial acoustic gel. One advantage identified by the OPG was its low volatility compared to the widely used commercial alcohol-based gel. Compared to OPG, an alcohol-based commercial gel readily evaporates, requiring more volume to complete a single ultrasound test.

CONCLUSION

In conclusion, the study showed that OPG had an optimum appearance, texture, homogeneity, and pH value. Although there is a difference in spreadability, pH, and viscosity between OPG and commercial gel, there was no significant difference in the image quality parameters between the gels used in the study. The sonologists noted that one of the significant advantages of OPG was its low volatility compared to the widely used commercial alcohol-based gel. Based on physical assessment, pH, spreadability, image quality, and subjective assessment, OPG is a cost-effective alternative to commercial acoustic gel. Further clinical trials involving actual patients are recommended to increase the validity of the results of the study.

Areas of further research may be undertaken. First, future investigations may be conducted to optimize the viscosity of OPG. Second, the test of stability on organoleptic characteristics, viscosity, pH, spreadability, and image quality parameters may be carried out over a period of time to observe changes in the OPG properties. Third, in future studies, actual patients in low-resource settings may be scanned. Although other plant-based gel may be tested, this study is the first to explore and demonstrate the feasibility of OPG as a low-cost alternative to commercial acoustic gel.

REFERENCES

ABO A. 2014. Physics and knobology. In: Pediatric Emergency and Critical Care Ultrasound. Doniger SJ ed. United Kingdom: Cambridge University Press. p. 4–20.

ALIPIO MM, QUESTO DLR, SUBANG DMI, TAN LA. 2019. Saluyot (*Corchorus olitorius* L.) leaves as acoustic gel for ultrasound imaging. CMU J Sci 23(2): 28–32.

ANDRADE AO, PARENTE ME, ARES G. 2014. Screening of mucoadhesive vaginal gel formulations. Braz J Pharm Sci 50(4): 931–941.

AZIZ A, DAR PE, HUGHES F, SOLORZANO C, MULLER MM, SALMON C, SALMON M, BENFIELD N. 2018. Cassava flour slurry as a low-cost alternative to commercially available gel for obstetrical ultrasound: a blinded non-inferiority trial comparison of image quality. BJOG 125(9): 1179–1184.

BINKOWSKI A, RIGUZZI C, PRICE D, FAHIMI J. 2014. Evaluation of a cornstarch-based ultrasound gel alternative for low-resource settings. J Emerg Med 47(1): e5–e9.

BRADLEY K. 2019. Ultrasound machine knobology. Top Companion Anim Med 24(1): 19–23.

BUSHONG SC. 2013. Radiologic science for technologists: physics, biology, and protection. Amsterdam: Elsevier. 672p.

CABRELLI LC, PELISSARI PI, DEANA AM, CARNEIRO AA, PAVAN TZ. 2016. Stable phantom materials for ultrasound and optical imaging. Phys Med Biol 62(2): 432.

CHAUDHARY B, VERMA S. 2014. Preparation and evaluation of novel in situ gels containing acyclovir for the treatment of oral herpes simplex virus infections. Sci World J. Article ID 280928.

DIMIC-MISIC K, NIEMINEN K, GANE P, MALONEY T, SIXTA H, PALTAKARI J. 2014. Deriving a process viscosity for complex particulate nanofibrillar cellulose gel-containing suspensions. Appl Rheol 24(3): 43–51.

DURAZZO A, LUCARINI M, NOVELLINO E, SOUTO EB, DALIU P, SANTINI A. 2019. *Abelmoschus esculentus* (L.): bioactive components' beneficial properties—focused on antidiabetic role—for sustainable health applications. Molecules 24(1): 38.

ENRIQUEZ JL, WU TS. 2014. An introduction to ultrasound equipment and knobology. Crit Care Clin 30(1): 25–45.

FARHANA NA, AMIN I, HASSAN SA, SHUHAIMI M. 2017. Gel formation of pectin from okra (*Abelmoschus esculentus* L. Moench) leaves, pulp and seeds. Int Food Res J 24(5): 2161–2169.

GEMEDE HF, HAKI GD, BEYENE F, RAKSHIT SK, WOLDEGIORGIS AZ. 2018. Indigenous Ethiopian okra (*Abelmoschus esculentus*) mucilage: a novel ingredient with functional and antioxidant properties. Food Sci Nutr 6(3): 563–571.

HABTAMU FG, NEGUSSIE R, GULELAT DH, WOLDEGIORGIS AZ, FEKADU B. 2015. Nutritional quality and health benefits of okra (*Abelmoschus esculentus*): a review. Pak J Food Sci 25(1): 16-25.

LUEWAN S, SRISUPUNDIT K, TONGSONG T. 2007. A comparison of sonographic image quality between the examinations using gel and olive oil, as sound media. J Med Assoc Thai 90(4): 624–627.

MILTON SC, CRONIN AJ, MONTI JD. 2018. Evaluation of glucomannan powder as an ultrasound transmission gel alternative for resource-constrained environments: a prospective, comparative study. Wilderness Environ Med 29(4): 446–452.

MINA CD, REYES CM, GLORIA RA, MERCADO SJ. 2015. Review of design and implementation of the agricultural insurance programs of the Philippine Crop Insurance Corporation. PIDS Discussion Paper Series.

MONTI JD. 2017. A novel ultrasound transmission gel for resource-constrained environments. J Spec Oper Med 17(1): 22–25.

SALMON M, SALMON C, BISSINGER A, MULLER MM, GEBREYESUS A, GEREMEW H, WENDELL S, AZAZA A, SALUMU M, BENFIELD N. 2015. Alternative ultrasound gel for a sustainable ultrasound program: application of human centered design. PloS One 10(8): e0134332.

SINGH P, CHAUHAN V, TIWARI BK, CHAUHAN SS, SIMON S, BILAL S, ABIDI AB. 2014. An overview on okra (*Abelmoschus esculentus*) and its importance as a nutritive vegetable in the world. Int J Pharm Biol Sci 4(2): 227–233.

TAMAYOL A, AKBARI M, ZILBERMAN Y, COMOTTO M, LESHA E, SEREX L, BAGHERIFARD S, CHEN Y, FU G, AMERI SK, RUAN W. 2016. Flexible pH-sensing hydrogel fibers for epidermal applications. Adv Healthc Mater 5(6): 711–719.

TEMPKIN BB. 2014. Sonography scanning: principles and protocols, 4th ed. Amsterdam: Elsevier. 704p.

TYAGI S, SHARMA N, GUPTA SK, SHARMA A, BHATNAGAR A, KUMAR N, KULKARNI GT. 2015. Development and gamma scintigraphical clearance study of novel *Hibiscus rosa-sinensis* polysaccharide based mucoadhesive nasal gel of rizatriptan benzoate. J Drug Deliv Sci Technol 30: 100–106.

VERNON LP, SEELY GR. 2014. The chlorophylls. United States: Academic Press. 696p.