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# Evaluation of Imaging Analysis with the Use of Oral Contrast Media for Abdominal MRI

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**The purpose of this study was to provide preliminary experimental data on the utility of a new oral contrast media for abdominal MRI contrast imaging examination. In the experimental study, the following oral contrast media were used: Solotop® (Taejoon Pharmacal, Seoul, Korea), diatrizoate meglumine (Gastrografin®, Schering, Berlin, Germany), 50 % blueberry juice, 100 % orange juice, 3.5 % blueberry juice. The GE Signa Excite HD 1.5 T MR system and an 8-channel CTL (cervical thoracic lumbar) coil were used to obtain. T1- and T2-weighted images, and the acquired SNR and CNR values of the contrast media were analyzed by multi-way ANOVA. Fruit juice was lower than water in T2-weighted images and showed relatively higher contrast than did chemical contrast media. On the other hand, T1-weighted images showed a relatively low-contrast effect due to the moisture contained in the fruit juice. For the T1-weighted images, Gastrografin® and Solotop® had higher CNR and SNR than did the fruit juice contrast media. There was a statistically significant difference between water and oral contrast media ($p < .05$). Fruit juice having lower absolute water content than water showed lower T2 signal value than did water. Fruit juice having a viscosity higher than that of water had the advantage of being able to get distributed evenly in a desired organ. With further advanced studies based on these experimental results, an alternative oral contrast media could be developed, and abdominal MRI could be expected to be actively applied in clinical practice.**

**Keywords :** experimental study, juice, MRI, oral contrast media

## 1. Introduction

Magnetic resonance imaging (MRI) is a method of obtaining anatomical and physiological information about the human body based on the varied resonance properties of the atoms in a living body, using a strong magnetic field and RF (radiofrequency) electromagnetic waves produced by superconducting magnets, without using radiation [1]. Because MRI does not involve the use of radiation, there is no radiation-based damage caused by ionizing radiation, and 2D and 3D stereoscopic images can be obtained [2]. At this time, if the image of the target site is incorrect or the lesion cannot be confirmed due to various reasons, the contrast media is administered orally or intravenously.

The density of the proton spins (the number of proton) is the main parameter controlling longitudinal and transverse relaxation times (T1 and T2) and intensity of the magnetic field. The signal intensity obtained from the MRI is determined. Increased proton density and reduced T1 increases signal intensity, while signal intensity decreases when either proton density or T2 decreases [3].

Oral voice contrast media are used for magnetic resonance cholangiopancreatography (MRCP) imaging, a type of MRI. Since the contrast media lowers the signal value of the target tissue and blood vessels, it in turn causes a reduction in the signal value of the gastrointestinal tract and relatively increases the signal value of the pancreatic duct obstructed by the gastrointestinal tract, thereby making it easier to observe pancreatic lesions [4]. The ideal contrast media for magnetic resonance imaging is not toxic, has no adverse effects, and gets evenly distributed in the target tissue [5]. Fruit juice meets these requirements and its use as a new low-cost contrast media with less burden on the patient is attracting attention.

This study was conducted using fruit juice as an oral


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contrast media that has a high moisture content and a suitable viscosity and is distributed evenly in the target organ. The purpose of this study was to provide preliminary data on the utility of a new oral contrast media that could be used for further development of oral contrast media for abdominal MRI contrast imaging.

## 2. Materials and Methods

### 2.1. MR and Contrast Media

The MRI apparatus used for the experimental study of abdominal MRI is shown in Fig. 1. The GE Signa Excite HD 1.5 T MR system (GE Medical System, WI, USA) was used. The coil used for the scan was an 8-channel cervical thoracic lumbar (CTL) coil. The oral contrast media used were water, Solotop® (Taejoon Pharmacal, Seoul, Korea), diatrizoate meglumine (Gastrografin®, Schering, Berlin, Germany), 50 % blueberry juice, 100 % orange juice, and 3.5 % blueberry juice.

### 2.2. Experimental Examination

Chemical contrast media and fruit juice contrast media were prepared by filling 10 mL syringes with 6 mL of syringes, followed by 50 mL of Solotop®, Gastrografin®, 50 % blueberry juice, 100 % orange juice, and 3.5 % blueberry juice. The prepared contrast media were arranged in the MRI apparatus to obtain the magnetic resonance signal values. The coil used in this study was an 8-channel CTL coil, and each contrast media was scanned once to obtain T1-weighted images. The parameters used were TR (650 ms)/TE (8 ms), 23 echo train length, 41.67 Hz bandwidth, 30 cm FOV (field of view), 4.0 mm slice thickness, 4 NEX, A 384 × 256 matrix, and a 90° flip angle (Table 1).

The parameters were adjusted to obtain T2-weighted images and each contrast media was scanned once again. The parameters for the T2-weighted images were TR (3800 ms)/TE (100 ms), 23 echo train length, 41.67 Hz

**Fig. 1.** (Color online) The GE Signa Excite HD 1.5 T MR system (GE healthcare, Waukesha, WI, USA).

**Table 1.** Parameters of T1-weighted images.

| Parameter | Details |
|---|---|
| TR (ms) | 650 |
| TE (ms) | 8 |
| Echo train length | 23 |
| Bandwidth (Hz) | 41.67 |
| FOV (cm) | 30 |
| Slice thickness (mm) | 4.0 |
| NEX | 4 |
| Matrix | 384 × 256 |
| Flip angle (degree) | 90 |

**Table 2.** Parameters of T2-weighted images.

| Parameter | Details |
|---|---|
| TR (ms) | 3800 |
| TE (ms) | 100 |
| Echo train length | 23 |
| Bandwidth (Hz) | 41.67 |
| FOV (cm) | 30 |
| Slice thickness (mm) | 4.0 |
| NEX | 4 |
| Matrix | 448 × 256 |
| Flip angle (degree) | 90 |

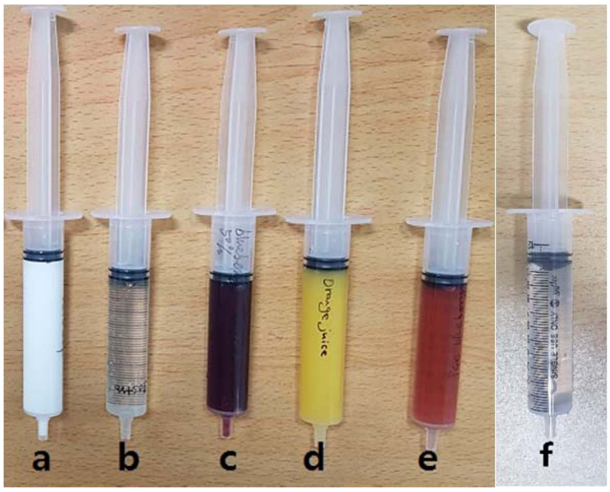



**Fig. 2.** (Color online) Contrast media used in the experiment were Solotop® (a), Gastrografin® (b), 50 % blueberry juice (c), 100 % orange juice (d), and 3.5 % blueberry juice (e). There were two kinds of chemical contrast media (a, b), three fruit-derived contrast media (c, d, e), and water (f).

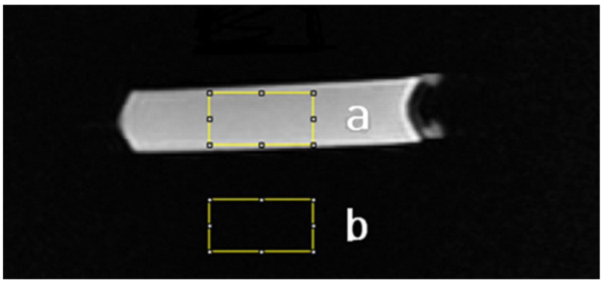



**Fig. 3.** (Color online) Measurement of the signal value using the ImageJ software (NIH, Bethesda, USA). The ROI (a), region of interest, is located in the contrast media, and the other ROI (b), background, is located outside the contrast media.

bandwidth, 30 cm FOV, 4.0 mm slice thickness, 4 NEX, 448 × 256 matrix, 90° flip angle (Table 2). T1- and T2-weighted images were obtained; the signal intensity of the contrast media and the noise from the tissue were calculated using ImageJ software (NIH, Bethesda, USA). The size of the ROI (region of interest) for measuring the tissue signal intensity and extracellular signal intensity was set at 2 × 1 cm.

Signal-to-noise ratio (SNR) is a measure of the image quality that can be obtained by dividing the tissue signal intensity by the signal intensity outside the tissue. Based on this, it was determined whether fruit juice could be used as an oral contrast media. SNR was calculated by dividing the measured signal by the background noise (Fig. 3). The contrast-to-noise ratio (CNR) is an index for evaluating the relative image quality, and was obtained by dividing the signal of the oral contrast media by the noise standard deviation (SD). In this experiment, the CNR value of the contrast media was calculated based on water [6].

$$\mathrm{SNR} = S/\sigma \quad (1)$$

$S$ is the signal intensity with the contrast media ROI, and $\sigma$ is the SNR by applying the standard deviation (SD) of the background.

$$\mathrm{CNR} = (SI_1 - SI_2)/(\sigma_1^2 + \sigma_2^2)^{1/2} \quad (2)$$

$SI_1$ and $SI_2$ are the phantom contrast signal intensities, and $\sigma_1$ and $\sigma_2$ are the CNR by applying the standard deviation (SD) of the background.

Multi-way ANOVA was performed using the SPSS PC$^+$ version 20 (IBM, Chicago, USA) to compare the mean of the SNR and CNR values with a 95 % confidence interval for the various oral contrast media used, and the statistically significant differences were analyzed. The post-analysis was conducted using the Dunnett T3 test post-test without assuming equal distribution. Statistical significance of the data was analyzed when the p-value was less than 0.05.

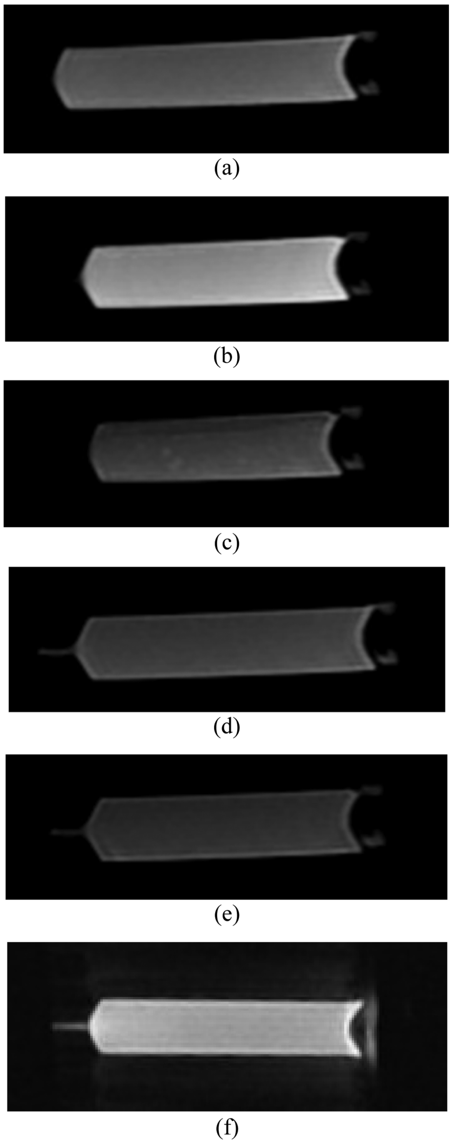
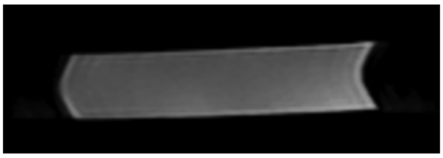



**Fig. 4.** Each contrast media was examined using a T1-weighted sequence. The contrast media used were Solotop® (a), Gastrografin® (b), 50 % blueberry juice (c), 100 % orange juice (d), 3.5 % blueberry juice (e), and water (f).

## 3. Results

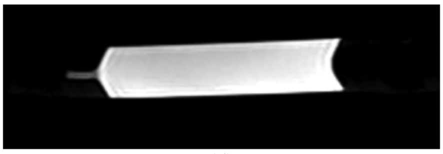
The contrast media used in the experiment was scanned once for each T1 and T2 emphasized sequences. The T1-weighted image is a sequence that whitens the fat signal and darkens the water signal. On the other hand, T2-weighted images emphasize water signals whiteness and show fat signals black. In the T1-weighted images, the SNR values of Gastrografin® (193.55), Solotop® (123.81), 50 % blueberry juice (119.22), 100 % orange juice



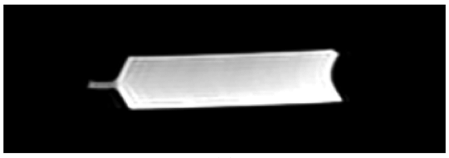
(a)

(b)

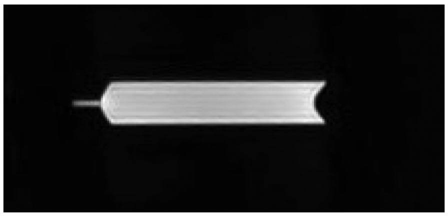
(c)



(d)



(e)



(f)

**Fig. 5.** Each contrast media was examined using a T2-weighted sequence. The contrast media used were Solotop® (a), Gastrografin® (b), 50 % blueberry juice (c), 100 % orange juice (d), 3.5 % blueberry juice (e), and water (f).

(109.05), and 3.5 % blueberry juice (77.12). The SNR values of Gastrografin® and Solotop®, which are X-ray contrast media, were high. Fruit juice contrast media showed lower signal than did the chemical contrast media. CNR was based on water, and was highest for Gastrografin® (–68.5), followed by Solotop® (–30.1), 50 % blueberry juice (–16.1), 100 % orange juice (–12.92), and 3.5 % blueberry juice. The CNR values of the T1-weighted images showed a higher contrast value than water and the value of Gastrografin® was the lowest. There was a statistically significant difference between

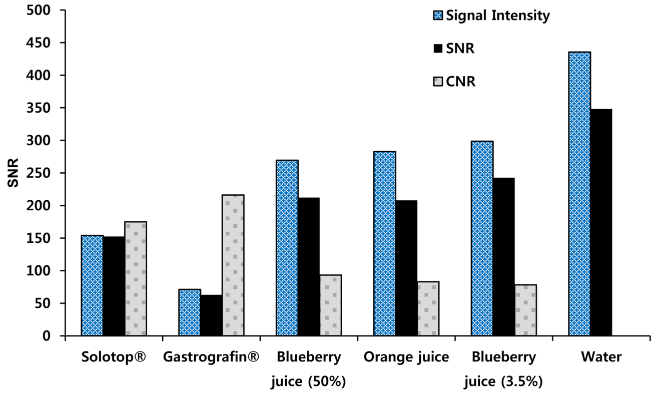



**Fig. 6.** (Color online) SNR, CNR, and signal intensity of the oral contrast media for T1-weighted images.

water and oral contrast media ($p < .05$). Figure 6 shows that on T1-weighted images, Gastrografin® and Solotop® showed higher values of SNR and CNR than did the fruit juice contrast media.

The T2-weighted images showed SNR values of 348.34, 3.52 %, 242.7 %, blueberry juice 50 %, 212.11, orange juice 100 %, Solotop® 152.51, Gastrografin® (63.05). SNR showed high SNR values for water and fruit juice contrast media. The chemical contrast media showed a lower signal value than did the fruit juice contrast media. CNR was based on water, and the CNR values of the T2-weighted images were highest for Gastrografin® (216.02), followed by Solotop® (174.85), 50 % blueberry juice (93.2), 100 % orange juice (82.83), and 3.5 % blueberry juice (78.12). The CNR values of T2-weighted images were high with Gastrografin® (216.02) and Solotop® (174.85). There was a statistically significant difference between water and oral contrast media ($p < .05$). Figure 7 shows that on T1-weighted images, Gastrografin® and Solotop® showed higher CNR and SNR than did fruit juice contrast media.

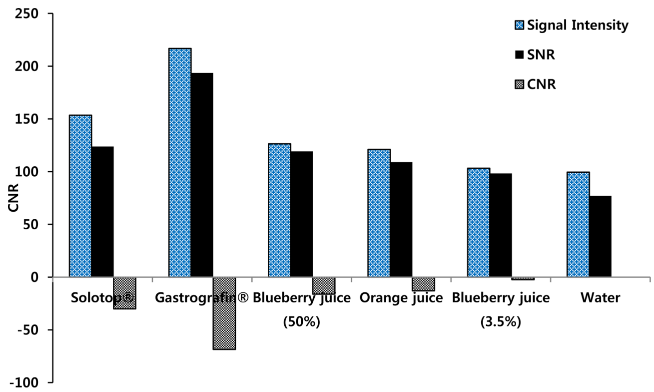



**Fig. 7.** (Color online) SNR, CNR, and signal intensity of the oral contrast media for T2-weighted images.

**Table 3.** SNR and CNR values of T1-weighted images for oral contrast media.

| Contrast Media | Signal | Signal of Background (Mean ± SD) | SNR | CNR | *p*-value |
|---|---|---|---|---|---|
| Solotop® | 153.528 | 7.07 ± 1.24 | 123.81 | –30.1 | < .05 |
| Gastrografin® | 216.775 | 6.77 ± 1.12 | 193.55 | –68.5 | < .05 |
| Blueberry juice (50 %) | 126.373 | 7.14 ± 1.06 | 119.22 | –16.1 | < .05 |
| Orange juice (100 %) | 121.046 | 7.11 ± 1.11 | 109.05 | –12.92 | < .05 |
| Blueberry juice (3.5 %) | 103.265 | 6.58 ± 1.05 | 98.35 | –2.40 | < .05 |
| Water | 99.49 | 6.84 ± 1.29 | 77.12 | | |

**Table 4.** SNR and CNR values of T2-weighted images for oral contrast media.

| Contrast Media | Signal | Signal of Background (Mean ± SD) | SNR | CNR | *p*-value |
|---|---|---|---|---|---|
| Solotop® | 154.032 | 6.68 ± 1.01 | 152.51 | 174.85 | < .05 |
| Gastrografin® | 71.249 | 7.99 ± 1.13 | 63.05 | 216.02 | < .05 |
| Blue berry juice (50 %) | 269.384 | 7.5 ± 1.27 | 212.11 | 93.20 | < .05 |
| Orange juice (100 %) | 282.744 | 7.7 ± 1.36 | 207.9 | 82.83 | < .05 |
| Blue berry juice (3.5 %) | 298.519 | 7.14 ± 1.23 | 242.7 | 78.12 | < .05 |
| Water | 438.050 | 6.91 ± 1.25 | 348.34 | | |

## 4. Discussion

Currently, X-ray, computed tomography (CT), and fluoroscopic methods are used for diagnosing abdominal diseases in clinical practice; ultrasonography is also used. However, the diagnostic use of X-rays causes inevitable radiation exposure to the patient, and the use of ultrasound has various limitations because the image is produced by reflected waves. Therefore, abdominal MRI has been suggested as an alternative. Because the abdominal MRI scan uses magnetic resonance, exposure to radiation can be avoided, and good quality images can be obtained by carefully examining the artifacts. In addition, when performing an abdominal MRI, the contrast media can be administered orally, which makes it easier to observe the lesion, since the signal values of the target tissue and blood vessel can be regulated artificially.

An experimental study on oral contrast media for abdominal MRI in Korea was conducted using diethylenetetramine penta-acetic acid (Gd-DTPA) and barium sulfate [7]. In this study, Gd-DTPA showed the highest signal value on T1-weighted images and was found to be suitable for use as an oral contrast media. Additionally, gels or liquid medicines (Mylanta®, Talcid®, Gelfos®, Legalon®, Bacchus®, Yeongbichun®, Ssanghwatang®) and beverages (milk, soy milk, yogurt, orange juice, apple juice) have been studied. Gd-DTPA, Gelfos®, and Legalon®, which have higher signal values on the T1-weighted images, have been shown to be clinically useful as benign contrast media [8].

In other countries, pineapple juice (2.76 mg/dL) concentrated in the diagnosis of pancreatic duct was applied to MRCP using a fruit juice contrast media containing iron oxide, which was relatively strong compared to the uniformity of the magnetic field [9]. Diagnostic ability may be affected when evaluating the gastrointestinal tract in normal T2- and T1-weighted images. MRCP or T2-weighted images with a short or media TE affect gastrointestinal fluid removal. The negative contrast effect of pineapple juice was due to a decrease in signal intensity from the fluid in the gastrointestinal tract on T2-weighted images, which was further caused by the shortening of the T2 relaxation time. This appears to be a paramagnetic effect caused by relatively high concentrations of manganese in pineapple juice [9]. In other reports, pineapple juice has been recommended as an ideal alternative to chemical contrast media commonly used for MRCP because of its role in suppressing the gastric juices and preventing the occurrence of overlapping artifacts due to paramagnetic properties. Additionally, the use of pineapple juice as a contrast media has been reported to have no adverse effects on human subjects [10, 11]. Further studies need to be applied to the abdominal examination with the addition of a variety of contrast media, including pineapple juice, to the clinic.

However, currently, abdominal magnetic resonance imaging with an oral abdominal MRI contrast media is very rare in clinical settings in Korea. It is expected that patients with abdominal gastrointestinal diseases would be diagnosed with magnetic resonance imaging if a product

Table 5. Contents of the used fruit juices [13, 14].

| Materials | Manufacturer | Description as purchased | Energy (kcal) | Protein (g) | COH (g) | Fat (g) | Iron (mg) | Manganese (mg) | Copper (mg) |
|---|---|---|---|---|---|---|---|---|---|
| Orange | Sainsbury's | Pure orange juice | 47 | 0.5 | 9.0 | Trace | 0.12 | 0.04 | 0.02 |
| Blueberry | Sainsbury's | Blueberry juice drink | 44 | 0.1 | 10.5 | Trace | 0.28 | 0.33 | 0.06 |

which is less expensive than the chemical contrast media is developed which can be applied to the human body. In this experimental study, it is expected that the oral contrast media, which are harmless to the human body, can be used for clinical abdominal MRI [12].

The blueberry juice had the highest SNR after T2 on the T2-weighted image. This is mainly due to the $Mn^{2+}$ ions in the signal intensity change caused by the blueberry juice. Manganese content is reported to be high as shown in Table 5 [13, 14]. In this experiment, SNR and CNR values were measured for orange juice and blueberry juice. The SNR of orange juice and blueberry juice were high, and the CNR values were similar to that of water on T2-weighted images. The reason for the high signal intensity of orange juice and blueberry juice on T2-weighted images is that the juice itself contains an appropriate amount of water. As shown in Table 5, the oral contrast media of fruits made of commodities contains the metals [13, 14].

The relaxation stress effect of blueberry juice is mainly due to $Mn^{2+}$ ions and can be controlled by changing manganese concentration. In electron spin resonance, manganese in blueberry juice is present as a divalent ion. Manganese is one of very few indispensable factors, and the dietary requirement for humans is 3-10 mg/d, but the amount of manganese consumed varies with the dietary intake of manganese-rich foods [15]. Only 3 to 4 % of the manganese consumed through food is activated and absorbed. At appropriate concentrations, blueberry juice was reported to be an effective oral contrast media for the abdominal and hepatic biliary systems, and this study also showed high SNR on T2-weighted images [16].

The limitations of this experiment are as follows. First, this experimental study used a 1.5 T GE signa Excite HD MR system, but could not compare the intensity of the magnetic field strength of 1.5 T or higher. Second, only orange juice and blueberry juice were used in the experiment, thus this study did not involve the use of a wide variety of fruit juices. Third, this study used phantoms, and did not involve clinical patients.

## 5. Conclusion

Fruit juice was lower than water in T2-weighted images and showed relatively higher contrast than did chemical contrast media. On the other hand, T1-weighted images showed relatively low contrast. This suggests that the water content in the fruit juice caused an enhancement effect in MR images. Fruit juice has a lower absolute water content than does water, and shows lower T2 signal value than does water; however, it has a viscosity higher than that of water and therefore can be distributed evenly in a desired organ, which is advantageous. Further studies conducted based on the present study could help in the development of alternative oral contrast media; abdominal MRI can then be expected to be actively applied in clinical practice.

## References

[1] Y. S. Han, S. C. Lee, D. Y. Lee, J. W. Choi, J. W. Lee, and D. C. Kweon, J. Magn. **21**, 115 (2016).
[2] M. Zarrini, F. S. Toosi, B. Davachi, and S. Nekooei, Revi. Clin. Med. **2**, 200 (2015).
[3] C. F. Geraldes and S. Laurent, Contrast Media Mol. I. **4**, 1 (2009).
[4] P. Nikolaos, K. Apostolos, M. Thomas, and G. Nickolas, J. Comput. Assist. Tomogr. **24**, 229 (2000).
[5] D. A. Cory, D. J. Schwartzentruber, and B. H. Mack, Magn. Reson. Imaging. **5**, 65 (1985).
[6] C. S. Mooe, G. P. Liney, and A. W. Beavis, J. App. Clin. Med. Phys. **5**, 25 (2004).
[7] J. W. Yeon. Inha University (1997).
[8] G. Heo, Y. H. Kim, S. J. Cha, W. H. Cho, W. H. Kim, and J. S. Kim, Inje Med. J. **15**, 105 (1994).
[9] R. D. Riordan, M. Khonsari, J. Jeffries, G. F. Maskell, and P. G. Cook, Br. J. Radiol. **77**, 991 (2004).
[10] F. M. Alshehri, J. Clin. Diagn. Res. **9**, TC13 (2015).
[11] H. Sasani, A. Kayhan, M. Sasani, and M. Sansani, Biomed. Res. **28**, 5167 (2017).
[12] Y. Yamamoto and H. Hasegawa, H. Food Ingredients J. **203**, 281 (1993).
[13] O. J. Arthurs, M. J. Graves, A. D. Edwards, I. Joubert, P. A. Set, and D. J. Lomas, BMC Med. Imaging. **14**, 33 (2014).
[14] USDA National Nutrient Database (http://ndb.nal.usda.gov/).
[15] K. Hiraishi, I. Narabayashi, O. Fujita, K. Yamamoto, and A. Sagami, Radiology. **194**, 119 (1995).
[16] N. Papanikolaou, A. Karantanas, T. Maris, and N. Gourtsoyiannis, J. Comput. Assist. Tomogr. **24**, 229 (2000).