Physical and Chemical Characterization of Rice Using Microwave and Laboratory Methods

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Abstract

Two main species of cultivated rice in the world are *Oryza sativa* (Asian rice) and *Oryza glaberrima* (African rice). The *Oryza sativa* species, which is grown worldwide, is far more widely utilized compared with the *Oryza glaberrima* species, which is grown in West Africa. Recently, the annual rice production has reached almost 480 million tonnes, and this demand is expected to rise to 550 million tonnes in 2035. Thus, this increases the need to characterize and maintain the quality of rice and hence to determine the price of rice appropriately. Obviously, modern technologies that can provide fast and accurate measurement are essential in the large-scale industrial rice processing. In this chapter, several technologies and instruments used for rice processing are reviewed. The principle of the measurement for each technology is briefly described. The strength of this chapter is to introduce the application of microwave technology during rice processing, such as rice dying process, rice moisture detection, broken rice measurement and rice insect control. The pros and cons of the microwave method will be discussed in detail. Hence, some standard test laboratory for monitoring of carbohydrate, protein, fat and trace elements content is also described in this chapter.

Keywords: rice, rice physical properties, rice chemical properties, moisture, broken rate, protein, fat, carbohydrate

1. Introduction

There are more than 40,000 different types of rice in the world. However, commonly, rice is categorized by its physical shape and sizes or length either long grain, medium grain or short grain. Rice consists of two main species, which are *Oryza sativa* known as Asian rice and *Oryza glaberrima* known as African rice. *Oryza glaberrima* is less common as compared to

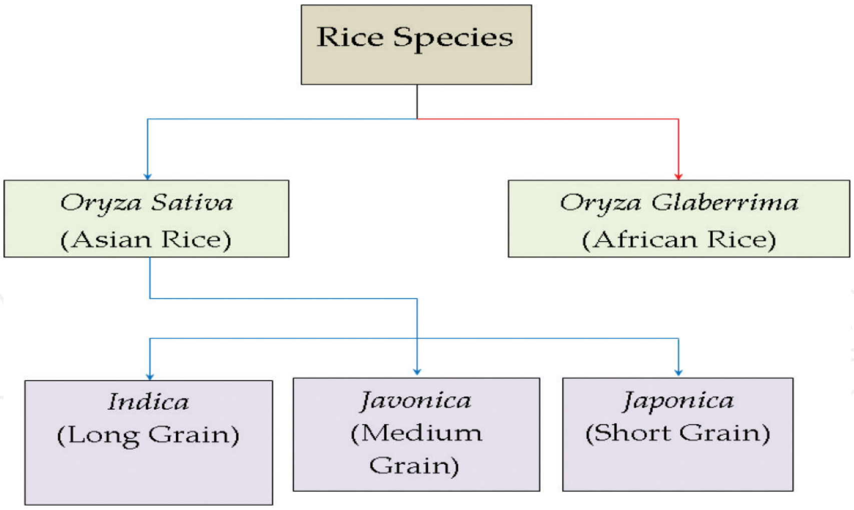


Figure 1. Categories of rice species.

Oryza sativa. *Oryza sativa* can be divided into *indica, javonica and japonica* subspecies as shown in **Figure 1**.

Oryza sativa Indica is known as long grain rice, which has a long and slender kernel. This type of rice is commonly grown in warm climate regions, such as at Thailand, India, Pakistan, Brazil and Southern USA. Furthermore, long grain rice is much fluffier and less sticky than short grain rice. On the other hand, medium grain rice has a size and length in between the other two subspecies grains that belong to *Javonica* group called *Oryza sativa Javonica*. It is shorter, plump and slightly wider than long grain rice but not round in shape and only found in Indonesia. Besides, the other type of grain rice, which is short and fat, that belongs to *Japonica* group is known as *Oryza sativa Japonica*. The short grain rice needs a cold weather environment to grow such as at Japan, Korea, Northern China and California. In particular, the short grain rice has high starch content, moist and viscous. The quality of milled rice is indicated by the combination of both physical and chemical characteristics. The physical characteristics of rice consist of milling degree, whiteness, grain shape, foreign matter, head rice, chalkiness and moisture content, *m.c.*, while the chemical characteristics are amylose content, gelatinization temperature and gel consistency [1]. However, the main characteristics used for milled rice grading are head rice, broken rice (BR) and brewer percentage, defectiveness, foreign matter, presence of paddy and *m.c.* [1].

2. Various manufactured brand of rice grain

There is existing variety of rice in the market, but most of the users are not experienced in distinguishing between the rice in terms of its physical and chemical properties. In this chapter, up to 10 types of commercial rice grain have been chosen to show the distinction between their properties, as well as the techniques used to characterize its properties. The basic physical properties (moisture content, *m.c.*, and size) of the 10 different brands of commercial rice are tabulated in **Table 1**.

Manufactured brand of rice	**Weight before heat (g)**	**Weight after heat m_d (g)**	**Weight losses m_w (g)**	**Moisture content *m.c.* (%)**	**Average length *l* (mm)**	**Average width *w* (mm)**
1. Sakura Super Thai Brown Rice	10.005	8.556	1.449	14.48	7.52	1.76
2. Jasmine Nutririce	10.003	8.524	1.479	14.79	7.29	2.04
3. Floral Glutinous	10.004	8.389	1.615	16.14	7.06	1.95
4. Maharaja Basmathi	10.009	8.377	1.632	16.30	6.79	1.52
5. SUMO Calrose	10.008	8.320	1.688	16.87	4.92	2.80
6. Bird of Paradise Thai Fragrant	10.010	8.303	1.707	17.05	7.18	1.86
7. Sakura Super Basmathi Pakistan	10.008	8.248	1.76	17.59	7.06	1.80
8. Giant Super Special White Rice	10.002	8.228	1.774	17.74	7.33	2.06
9. Sun Rise Australian Fragrant	10.005	8.203	1.802	18.01	7.22	1.90
10. Phkarkhnei Cambodi Organi	10.002	8.150	1.852	18.52	7.58	1.92

Table 1. Moisture content, *m.c.* and sizes of ten different brands of rice grain.

The actual *m.c.* of the rice grains in **Table 1** was obtained by the standard oven-drying method. Ten grams of each type of commercial rice grain was dried in a forced convection oven at 130°C for 24 h [2]. The *m.c.* was calculated in percent on the wet basis as:

$$m.c.(\%) = \frac{m_w}{m_w + m_d} \times 100 \tag{1}$$

where m_w and $m_d$are mass of water and dry grain, respectively. On the other hand, the average length, *l*, and width, *w*, for the 30 pieces rice grain from each type of bulk rice samples have been measured using digital vernier caliper. All the ten different types of rice samples showed the lowest moisture content, *m.c.* ranging from 14.48 to 18.52%. The length, *l*, and width, *w*, of the 10 samples are shown between 4.92–7.58 mm and 1.76–2.04 mm, respectively. More sophisticated ways to determine the physical properties of rice grain, as well as the rice processing using the latest technology, have been described in Sections 3.1–3.4. Meanwhile, the laboratory scientific methods used for testing the chemical properties have been described and discussed in detail in Section 3.5.

3. Applications of scientific methods and microwave equipments in rice processing

3.1. Rice drying and sterilization processing

The moisture content, *m.c.*, of the grain is the most important criteria for quality assessment and process control. The *m.c.* inside the rice grain is a crucial parameter for grain processing such as harvesting, milling, storage, transporting and quality control. For instance, rice grain is usually harvested between moisture content, *m.c.* 19–25% for maximum grain yield and needed to be dried to 14% or less depend on the season and the weather for safe storage [3]. Besides, the ideal *m.c.* for milling is 14% in order to maximize the head rice and minimize the broken rate (BR) [1]. If the *m.c.* in rice grain is too low, the milled grain will become fragile. Thus, precise determination of the rice grain *m.c.* is important. In general, the hot-air drying oven is implemented in conventional rice grain drying process. However, this method is time-consuming and causes energy loss. Recently, most of microwave equipments and measurement techniques are used to dry or monitor the moisture content, *m.c.*, inside the agriculture products and foods under test. The reason is because of the tendency of water to absorb microwave energy and generate the heat within the agri-foods under test. When the moist rice grain is exposed to the microwave, the water molecules in the rice grain will be induced to rotate and produce heat as shown in **Figure 2**. Thus, the rate of water removal is higher than hot-air drying method. Besides, the microwave heating is capable of maintaining original texture structure and color of the rice gain compared to conventional oven-drying techniques.

In fact, the interaction between agri-foods materials containing water with microwave can be described by the complex relative permittivity, ε_r:

$$\varepsilon_r = \varepsilon_r' - j\varepsilon_r'' \tag{2}$$

where the real part, ε_r'', is the dielectric constant and imaginary part, ε_r', is the dielectric loss factor. The ε_r'' influences the electric field distribution and the phase of waves traveling through the material. In contrast, the $\varepsilon_r\varepsilon$ influences the energy absorption or attenuation by the material.

The water removal rate of the rice grain is increased with the microwave power. However, the higher microwave power will increase the percentage of the broken milled rice and higher rate of oxidation as well as nutritional losses of the milled rice. Typically, the microwave oven

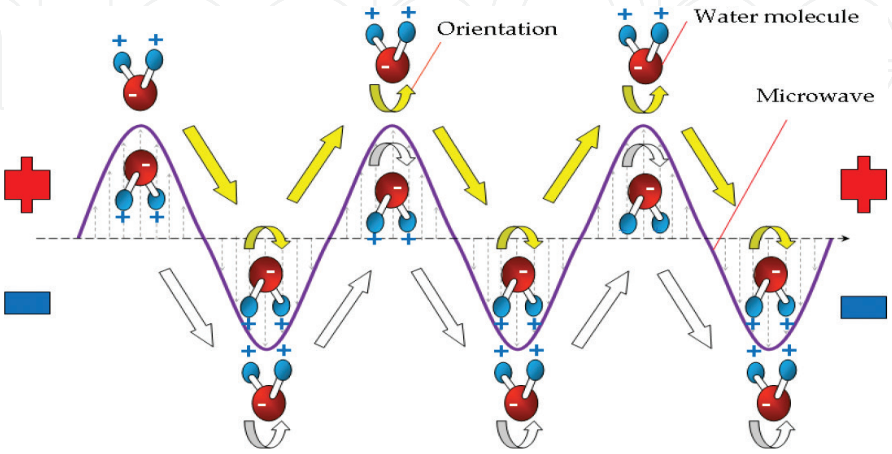


Figure 2. Microwave heating mechanisms: water molecules are oriented when exposed to microwave.

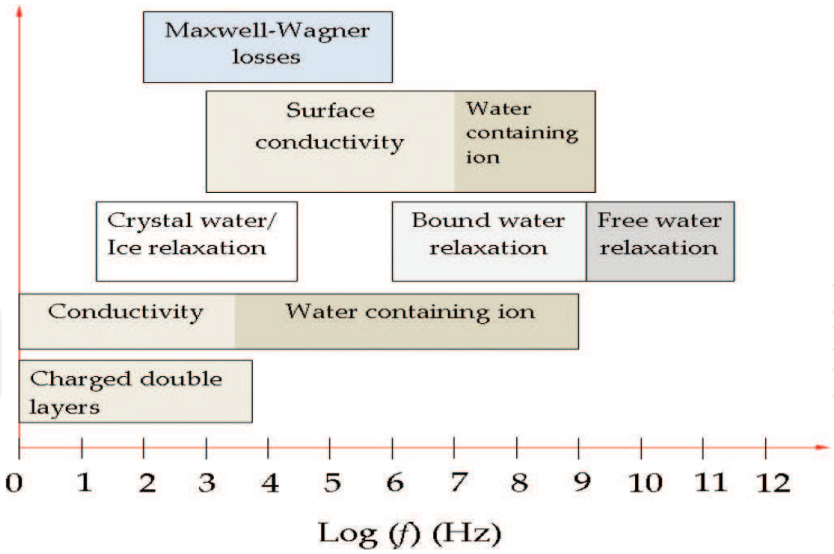


Figure 3. The mechanisms of water molecules when exposed to different range of operating frequency.

power will be adjusted to 55°C of heating temperature in order to reduce the *m.c.* of the rice grain from ~20 to 14% within 20 min [4]. The mechanisms of water molecules in agri-food specimens are different when exposed to different ranges of operating frequency, *f*, as shown in **Figure 3**.

There are two microwave frequencies allocated by the US Federal Communications Commission (FCC) for industrial, scientific and medical (ISM) use, which are 915 MHz and 2.45 GHz. Normally, most of the microwave heating applications are devoted to 2.45 GHz, since it provides a suitable compromise between power deposition and penetration depth, as well as it is an unlicensed operating frequency. For instance, the manufactured microwave heating system for agri-food products is shown in **Figure 4**.

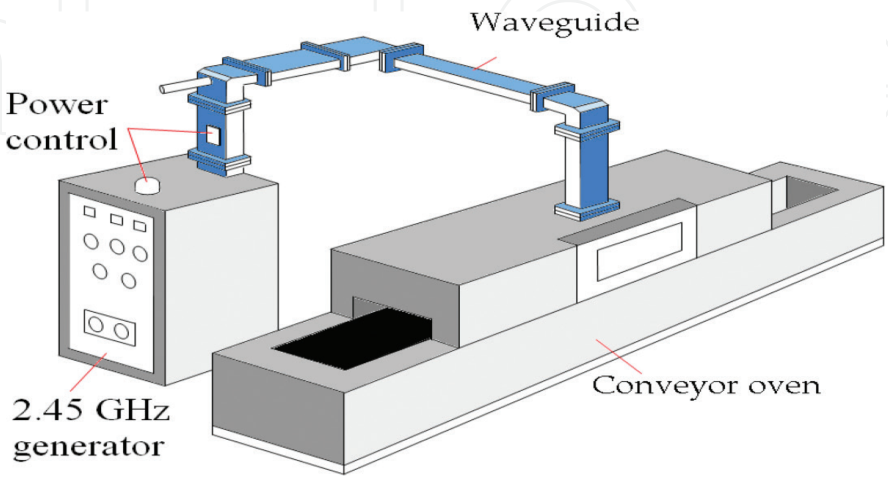


Figure 4. Microwave heating equipment.

3.2. Rice moisture sensing

There are two methods of determining moisture content, *m.c.*, of rice grain, which are the direct method and the indirect method. Direct method determines the *m.c.* by removing the *m.c.* of rice grain bulk using oven-drying method (130°C with 24 h) or chemical solvents as mentioned in Section 2. The direct method is the most accurate method to determine the grain *m.c.*, but it is time-consuming. For direct method, the water content in the rice grain is removed totally and *m.c.* is calculated from Eq. (**1**). The heating temperature must exceed the temperature of boiling water because water molecules in rice grain were bound with molecules of rice substance.

In contrast, the indirect method requires the measurement of the electrical property of the rice grain using fabricated instrument, so-called moisture meter. The change in electrical properties can be directly correlated with a change in the actual moisture content, *m.c.*, of the rice grain obtained from oven-drying method (direct method). Recently, the indirect methods become more popular than the direct method due to rapid test, high sensitivity and user-friendly features. In this section, only indirect methods that use high operating frequency for grain moisture determination are described.

As mentioned above, the polarization of water molecules contained in the rice grain is sensitive and showed a significant response when exposed to microwaves, and this will allow the microwave sensor to be used as a measuring technique to sense the moisture content, *m.c.*, in the moist rice grain. The volume of water in the total volume of moist rice grain heavily influences the relative permittivity of the moist rice grain due to the relative permittivity of pure water ($\varepsilon_r \approx 80$ at very low frequencies) being much greater than that of the other constituents in the rice grain bulk (rice substance: $\varepsilon_r \approx 2.5$, air: $\varepsilon_r = 1$). Thus, when the amount of moisture changes in the rice grain, the sensor will measure a change in reflection/transmission coefficient or resonant frequency (from the change in permittivity) that can be directly correlated with a change in *m.c.* of the rice grain, which was obtained from oven-drying method previously.

In this section, some of the microwave sensors related to the grain moisture measurement are presented. A microwave microstrip ring resonator as miniaturized and nondestructive sensor for single wheat grain microwave estimation were reported by Abegaonkar et al. [5] as shown in **Figure 5**. The ring resonator was designed on an alumina substrate with a h of 0.635 mm and $\varepsilon_{r,sub}$ of 9.98 to resonate at 10 GHz.

In this study, a wheat grain was overlaid on the ring resonator and its corresponding measured resonant frequency f_r, bandwidth *BW* and quality factor *Q* were obtained from a scalar

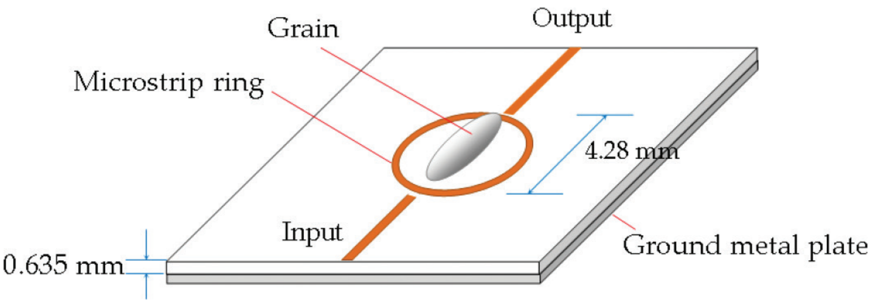


Figure 5. Microstrip ring resonator overlaid by grain [5].

network analyzer. Then, the calibration equations related to the moisture content, *m.c.* with f_r, $BW$and Q, respectively, were developed. Validation test showed that the average error for *m.c.* prediction was 2.12%. The major drawback of this ring resonator is that the grain orientation within the sensor significantly affects the accuracy and sensitivity of the measurement. Kim et al. [6] proposed a prototype microwave transceiver grain moisture meter based on free-space transmission method for rice grain *m.c.* prediction. The prototype grain moisture meter is mainly composed of oscillator, isolator, horn antenna, detector and rectangular grain holder. The schematic diagram of the prototype grain moisture meter is depicted in **Figure 6**. A generated microwave signal at 10.5 GHz from an oscillator is transmitted to the rice grain sample through an isolator and a transmitting horn antenna. The attenuated signal is then received by a receiving horn antenna and detected by a detector that converts the signal to voltage, V. A calibration equation, which relates the moisture content, *m.c.*, with moisture density, ε, voltage, V, and temperature, T, is developed and validated in this study. Validation result showed that the moisture meter can predict the *m.c.* with average error of 0.52%. However, the moisture meter is relatively large in size and operates at high frequency, which will increase its cost. In addition, the output voltage, V, of the meter needs to be substituted into the calibration equation manually for *m.c.* calculation.

A multilayer microstrip moisture sensor was developed by Jafari et al. [7] for measuring the *m.c.* of rice grain. The sensor was designed on a laminated RT/Duroid substrate with a h of 1.575 mm and $\varepsilon_{r,sub}$ of 2.2 to operate at 9 GHz. The sensor consists of two main parts: the stripline section, which is covered by aluminum plate, and the semi-infinite layer microstrip line, which is the

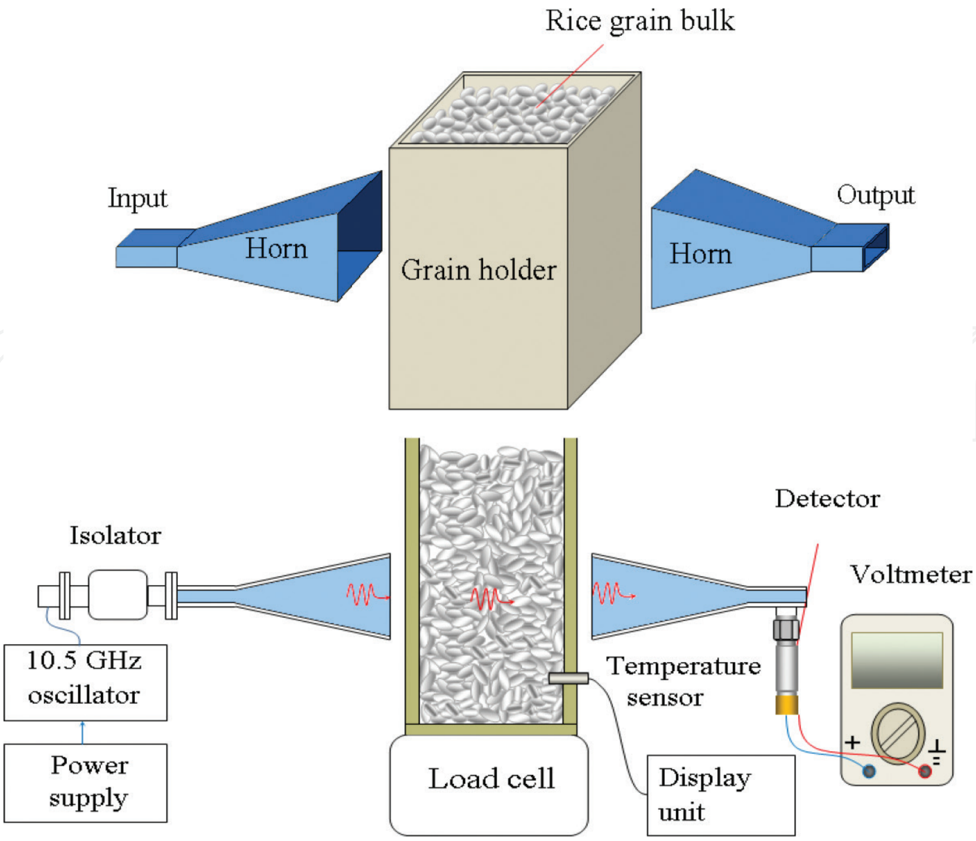
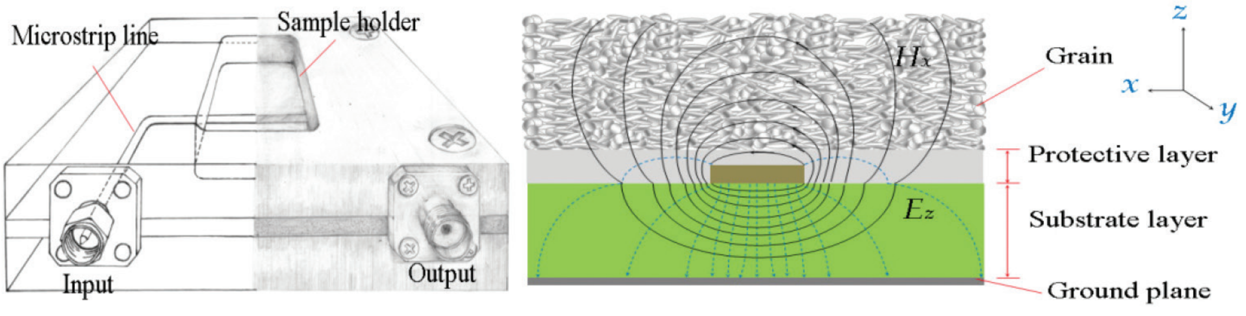


Figure 6. The prototype microwave transceiver grain moisture meter [6].

sensing region as shown in **Figure 7**. The attenuation as a function of complex permittivity of three dielectric layers (substrate, protective and grain layers) and effective dielectric constant was derived from complex propagation constant. Besides that, the relationship between the complex permittivity of rice grain and *m.c.* was also established based on mixture theory. To predict the *m.c.* of rice grain, the rice grain was loaded on the sensor and the corresponding attenuation signal was obtained from the vector network analyzer. Then, the *m.c.* was calculated from the measured attenuation through both derived attenuation and mixture equations based on numerical method. Thus, this method is complex as compared to aforementioned studies [5–6].

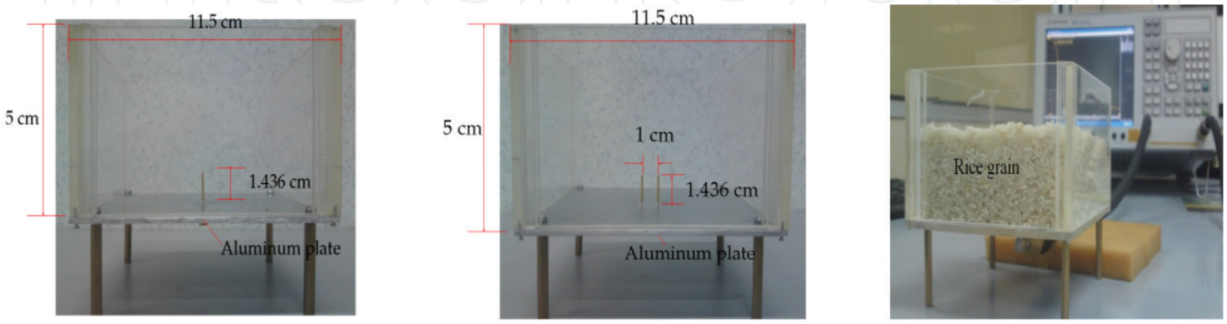
You et al. [8] proposed cylindrical slot antennas as sensors for rice quality (*m.c.* and percentage of BR) determination. A single slot antenna sensor and a coupling slots antenna sensor were fabricated by using SMA stub panel with a radius of 0.65 mm and length of 1.436 cm. For coupling slots antenna, the separation distance of the slots is 1 cm in which one of the slot was terminated. Both sensors were positioned on an aluminum ground plane with an acrylic holder. The configuration of the single slot antenna and coupling slot antenna sensors is illustrated in **Figure 8(a)** and **Figure 8(b)**, respectively.

Both sensors were designed to operate at 1 GHz for *m.c.* measurement based on the measured magnitude of reflection coefficient from a vector network analyzer. Calibration equations based on the relationship between the measured magnitude of reflection coefficient and *m.c.* were also developed for both sensors. The coupling slots sensor was more sensitive to



(a) (b)

Figure 7. (a) Multi-layer microstrip moisture sensor. (b) Cross section of microstrip sensing region [7].



(a) (b) (c)

Figure 8. Configuration of the (a) single slot sensor and (b) ccoupling slots sensor [8]; (c) Eexperiment- set-up.

the *m.c.* of the rice grain than single slot sensor. The coupling effects between the two slots will increase the density of the sensing fields for the sensor. Recently, microstrip wide-ring, microstrip coupled-line [9] and small coaxial probe [10], as shown in **Figure 9**, have been used for rice moisture measurements. By using wide-ring and coupled-line sensors, the bulk rice grain samples with different levels of *m.c.* were placed into the sample holder of the sensor as shown in **Figure 10**. On the other hand, the small and slim coaxial probe has a small sensing area, which is able to cover the size of single rice grain and provides a single grain moisture measurement. Moreover, the single grain measurement does not depend on the bulk density of the rice grains, and thus, the uncertainty of bulk density in the rice measurement (due to a different rate of broken rice in the bulk grain) can be ignored.

The comparison of the measured ε_r' and ε_r'' for rice grain with various *m.c.* at 2.45 GHz by using the wide-ring sensor, coupled-line sensor, literature data [11] and small coaxial probe is shown in **Figure 11**. Obviously, the value of ε_r' for single rice grain measurement is much higher than the bulk rice measurements. This is because the bulk rice is composed of a mixture of air and rice grains. The measured ε_r' will affect by the volume of air gap in the total volume of the bulk rice grain since the value of ε_r' for the air is approximately unity which is being much lower than the constituents in the rice grain.

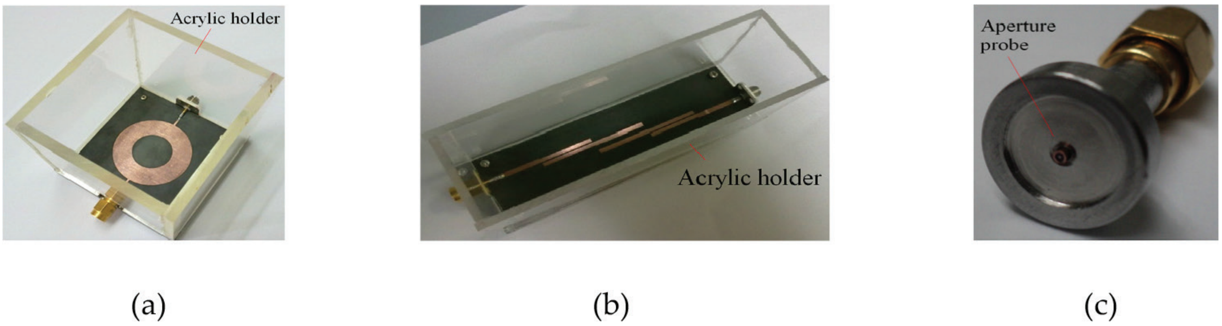


Figure 9. (a) Microstrip wide-ring sensor [9]; (b) microstrip coupled-line sensor [9]; (c) customized small coaxial probe with outer conductor radius $b = 0.33$ mm and inner conductor radius $a = 0.1$ mm [10].

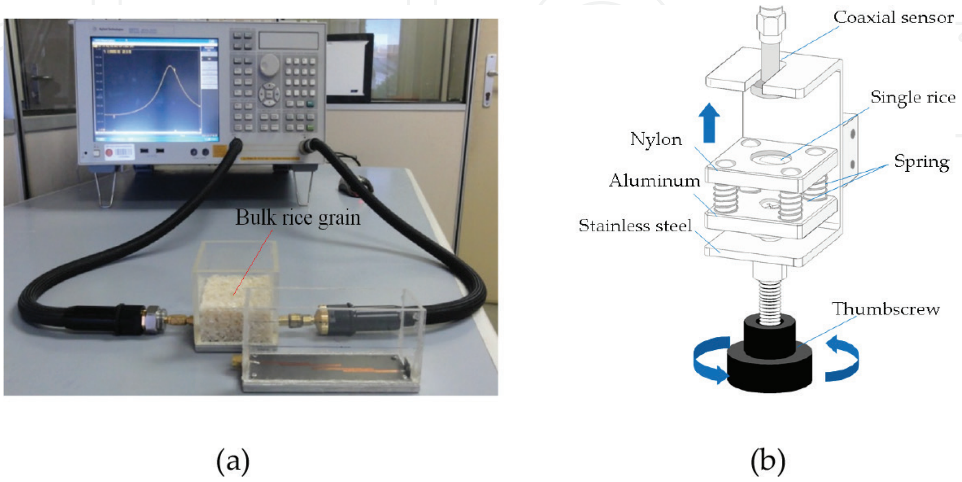


Figure 10. Measurement set-up for (a) bulk rice grain moisture measurement [9] and (b) single rice grain measurement [10].

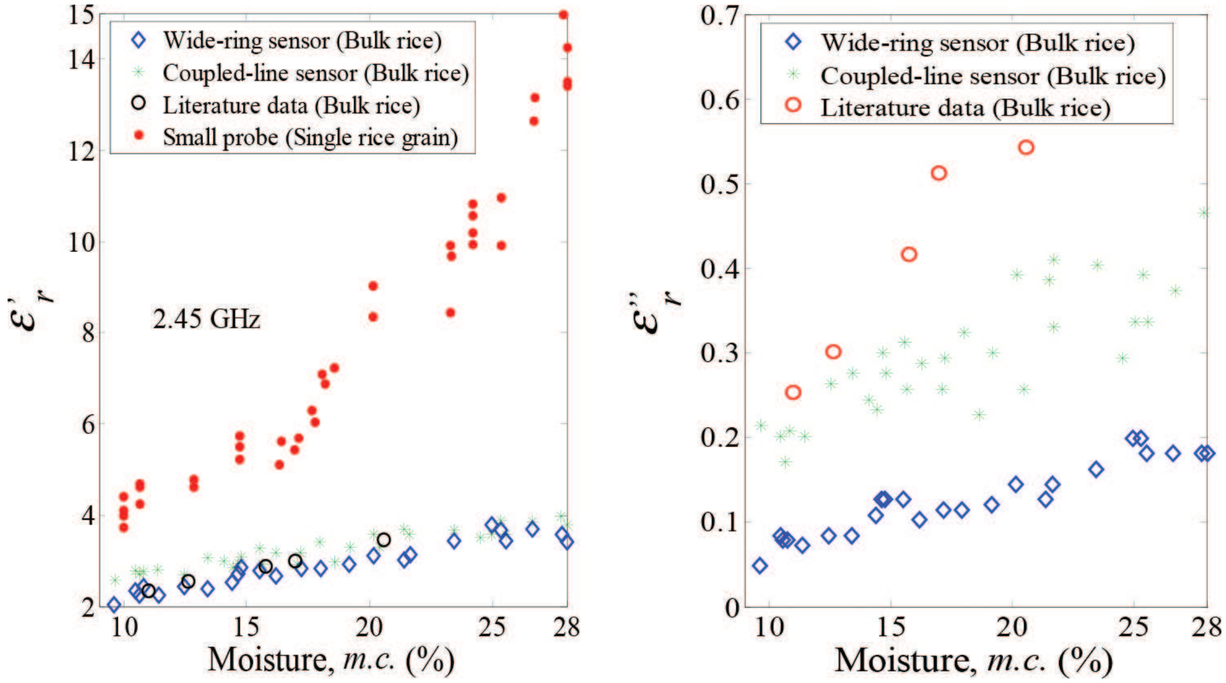


Figure 11. The variations in ε_r' and ε_r'' of single rice grain and rice grain bulk with its moisture content, *m.c.* at 2.45 GHz [10, 11].

3.3. Broken rice detection

The rice grain has a length <3/4 but more than 1/4 of the average head grain length are categorized as a broken rice as shown in **Figure 12**. Normally, the bulk rice, which contains broken grain for 0–5, 5–20, 20–35 and 35–50%, is classified as a premium grade, grade 1, grade 2 and grade 3, respectively. Using conventional broken rice sorting machine, the mechanical filter techniques are implemented. Since broken rice has a size smaller than head rice, the broken rice can be filtered by the wire net with small size of mesh in the machine. Recently, the image processing technique is popularly used for grading and classification of rice, in which the optical scanning is used to differentiate the size and color of the rice grain [12–14].

The optical techniques are able to recognize the ratio of broken rice and the impurities in bulk rice sample based on the pixel image area and pixel intensity for each rice grain. By using


(a) (b) (c)

Figure 12. The rice grain with (a) 0%, (b) 50% and (c) 100% broken rate.

the developed image processing software, the dimensional features of the rice kernels such as length, perimeter and projected area were extracted from the captured images. Empirical equations that relate the BR percentage and characteristic dimension ratio, which is computed from the dimensional features, were developed for percentage of BR estimation. The result showed that the BR percentage can be estimated with average error of 2%. For instance, in the work done by Lloyd et al. [13], a commercial GrainCheck machine vision system was evaluated to determine its performance in BR percentage measurement as shown in **Figure 13**. Most of the optical systems need to be controlled with various adjustments to acquire reproducible dimensional features from the capture images. Consequently, a trained operator is required to set up the system. Besides that, the rice kernels also need to be arranged manually to avoid any touching prior to the image capturing process. In addition, the machine is also large in size, expensive and affected by external light conditions.

In this section, an alternative broken rice measurement using microwave techniques is introduced. The measurement technique is based on the change in air gap density in the bulk rice, since the air gap between broken grains is smaller than the normal rice grains. The electromagnetic wave is generated from microwave sensor and radiated into the bulk grain sample. In fact, the air gap density in the grain sample is inversely proportional to the density of radiated field, which is covering inside the grain sample [15].

Besides moisture measurement, the cylindrical slot sensors in **Figure 8(a)** and **Figure 8(b)** (Section 3.2) can also be implemented for percentage of BR determination. In this BR percentage measurement, the sensors were operated at 13.5 GHz based on the measured magnitude of reflection coefficient $|\gamma|$ from a vector network analyzer. The short wavelength or high-frequency signal is required to enhance the air gap sensitivity for broken rice measurement and reduce the penetration of energy into the rice grains [8]. **Figure 14** shows the variation in measured reflection coefficient $|\gamma|$ of the rice grain with the percentage of broken rice in the samples at 13.5 GHz.

3.4. Rice insect detection and control

In addition to the above applications, microwave method can also be used to control and eliminate the rice weevils (in **Figure 16**) without affecting the texture of the rice grain. It is because each agri-food or biological specimen has unique energy absorption properties,

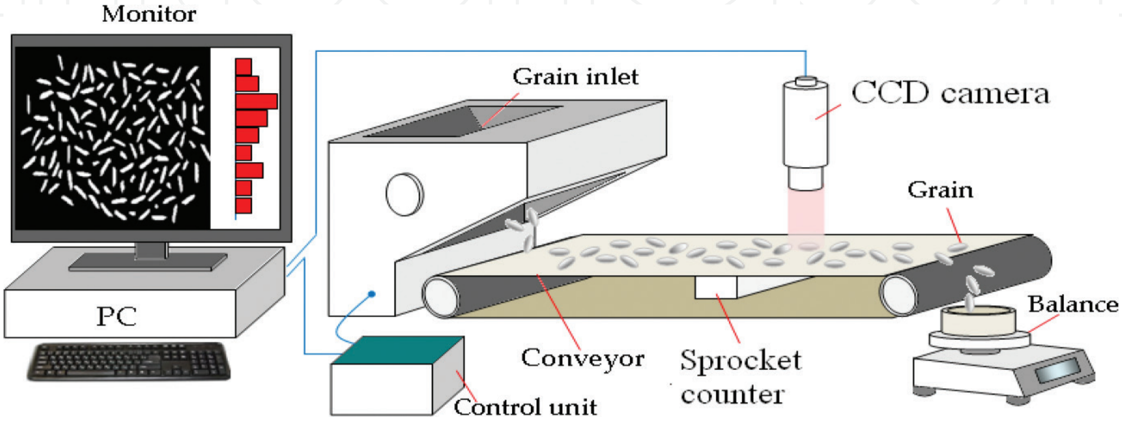


Figure 13. The GrainCheck machine vision system [13].

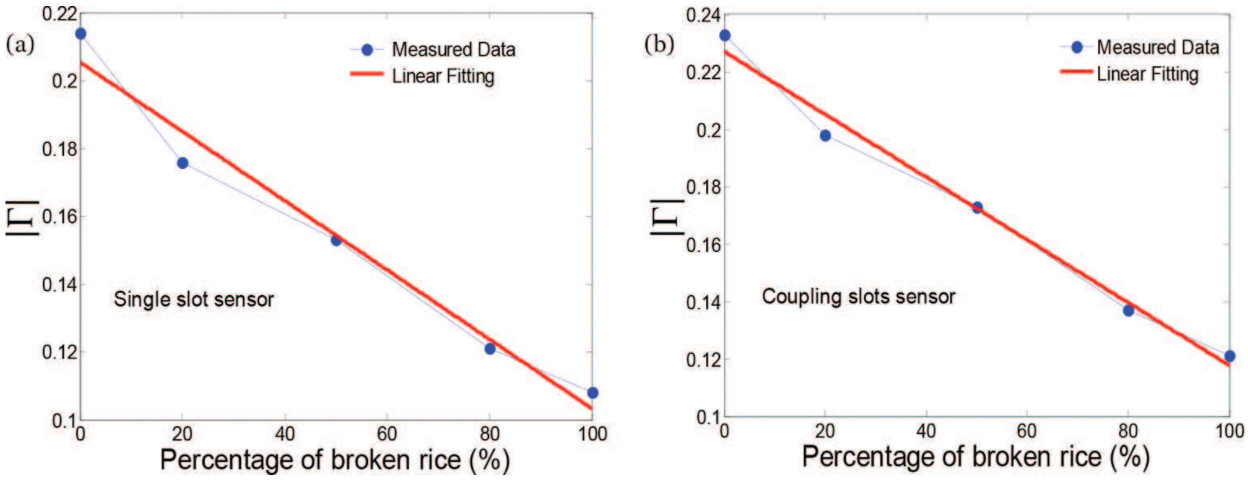


Figure 14. Variation in magnitude reflection coefficient |γ| with the percentage of broken grain in the bulk rice sample at 13.5 GHz using the (a) single slots sensor and (b) coupling slots sensor, respectively [8].

which is mainly influenced by its loss factor ε_r''. The value of ε_r'' for the material is frequency dependent. The typical relationship between the loss factor ε_r'', mechanism of water molecules and operating frequency is shown in **Figure 15**.

For instance, the values of ε_r' and ε_r'' of the rice weevils versus frequency *f* are shown in **Figure 16** [16] By comparing **Figure 15** and **Figure 16**, it was found that the water content in the rice weevils is in a state of bonding at a few MHz. This means that the internal response of the rice weevils is sensitive to the external wave at few MHz. Thus, Nelson et al. [16] found that the complete mortality of the rice weevils can be obtained with 40°C of grain temperature when infested grain was exposed to microwave at 39 MHz and then it was treated at 2.45 GHz (ISM band).

3.5. Rice nutrition test

3.5.1. Determination of total carbohydrate content by using phenol-sulfuric acid method

Hundred milligrams of each rice sample was weighed and hydrolyzed with 5 mL of 2N hydrochloric acid in a boiling water bath (80°C) for 1 h. The sample was left to cool at room

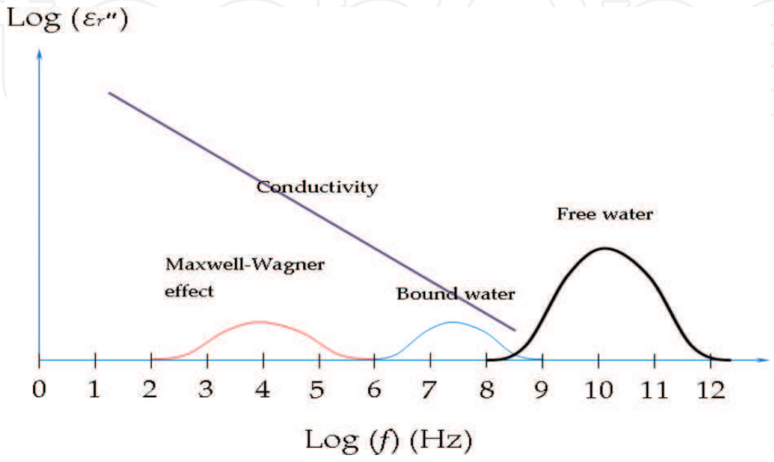
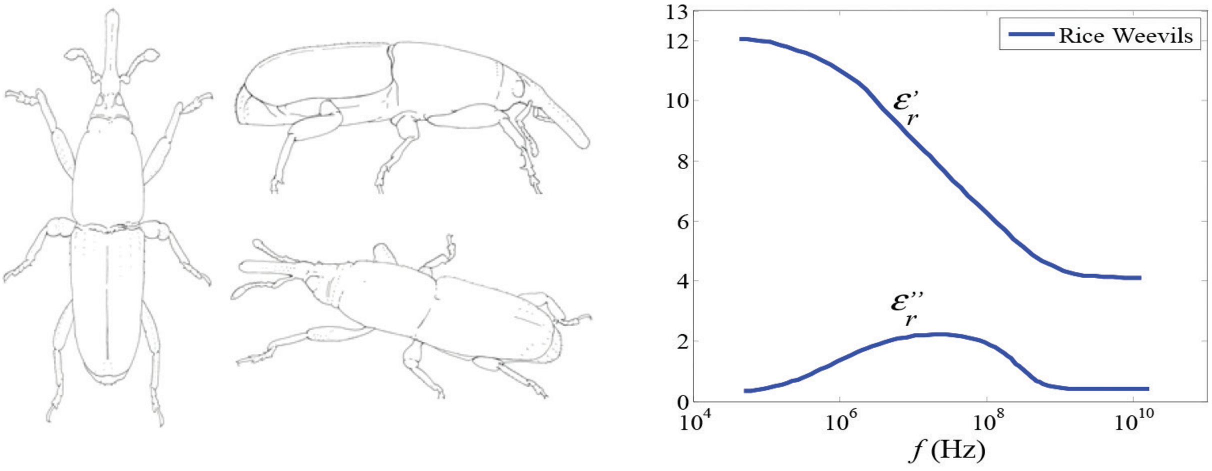


Figure 15. Relationship between ε_r'', mechanism of water molecules and frequency, *f*.



(a)

(b)

Figure 16. (a) Rice weevils (*Sitophilus oryzae*); (b) variation in ε_r' and ε_r'' of the rice weevils with frequency, f at 24°C [16].

temperature and neutralized with solid sodium carbonate, and then, distilled water was added to top the sample up to 100 mL. Meanwhile, the standard glucose solution was prepared by dissolving 100 mg of D-glucose with distilled water in a 100-mL volumetric flask. Ten milliliter of the standard glucose solution was further diluted to 100 mL, and the standard solution was used as working standard. A series of working standard of glucose solution was prepared by transferring 0.2, 0.4, 0.6, 0.8 and 1 mL of the working standard solution into five different volumetric flasks and topped up with distilled water (except the 1 mL sample) until the mark of 1 mL. On the other hands, 0.1 mL of the digested rice samples was pipetted and added with distilled water to bring the digests to 1 mL. Then, 1 mL of phenol solution (5%) and 5 mL of sulfuric acid (96%) were added to each digest, working standard and blank solution. All the digests, working standards and a blank solution were placed on a shaker and shook for 20 min to obtain homogeneous solutions. The amount of total carbohydrate content for all the digests, working standards and the blank was measured using an ultraviolet-visible spectrophotometer at 490 nm, and the absorbances were recorded as tabulated in **Table 2**.

As given in **Table 2**, the carbohydrate contents for the ten different rice samples were ranged from 43 to 88%. Floral rice sample gave the highest carbohydrate content (88%), while Phkarkhrrel rice sample had the lowest carbohydrate content (43%). The average carbohydrate content for the 10 different rice samples was 70.2%. This result was similar to the finding that obtained by Deepa and coworkers [17] on various Indian rice samples. The carbohydrate content of their analysis was ranged from 61.7 to 91.7% with the average value of 73.5%.

3.5.2. Determination of protein content by using Kjeldahl method

To determine the protein content in rice samples, 0.15 g of each sample was refluxed with 1 mL of mixed catalyst (96% sodium sulfate anhydrous and 3.5% copper sulfate) and 3 mL of concentrated sulfuric acid. When the sample solution was turned into green-blue, 30 mL of distilled water, 10 mL of 45% sodium hydroxide, 10 mL of 0.5 N hydrochloric acid and a few drops of methyl red indicator were added into the mixture. The ammonia solution produced

No.	Manufactured rice grain	Concentration of rice sample (mg/mL)	Total carbohydrate content (%)
1	Maharaja Basmathi	0.085	85
2	SUMO Calrose	0.072	72
3	Jasmine Nutririce	0.066	66
4	Floral Glutinous	0.088	88
5	Sun Rise Australian Fragrant	0.083	83
6	Bird of Paradise	0.055	55
7	Phkarkhrrel Cambodi Organi	0.043	43
8	Sakura Super Thai	0.086	86
9	Sakura Super Pakistan	0.073	73
10	Giant Super Special Rice	0.051	51

Table 2. Total carbohydrate content in rice samples from various brands.

from the reaction was distilled and collected in a conical flask. The distillate was titrated with 0.5 N sodium hydroxide solution in order to determine the protein content.

The results of the protein content analysis for the 10 different types of rice sample were ranged from 1.40 to 11.11% as shown in **Table 3**. The highest protein content was found in Jasmine rice (11.11%), and the lowest was the Sun rice (1.40%). The average protein content for the 10 different types of rice sample was 6.25%. This result is similar to the results obtained by Kenedy and Burlingame [18] who had done a comprehensive protein analyses on thousands of rice varieties from different regions of the world. The protein content for the rice samples ranged from 4.50 to 15.90%, with the mean value of 8.8%.

No	Manufactured rice	Volume of NaOH to titrate blank (mL)	Volume of NaOH to titrate HCl (mL)	% Nitrogen	% Protein (% nitrogen ×5.95)
1	Maharaja Basmathi	8.75	8.95	0.9333	5.55
2	SUMO Calrose	8.75	8.90	0.7000	4.17
3	Jasmine Nutririce	8.75	9.15	1.8667	1.11
4	Floral Glutinous	8.75	9.00	1.1667	6.94
5	Sun Rise Australian Fragrant	8.75	8.80	0.2333	1.40
6	Bird of Paradise	8.75	8.90	0.7000	4.17
7	Phkarkhrrel Cambodi Organi	8.75	8.90	0.7000	4.17
8	Sakura Super Thai	8.75	9.00	1.1667	6.94
9	Sakura Super Pakistan	8.75	9.05	1.6333	8.33
10	Giant Super Special Rice	8.75	9.10	1.6333	9.72

Table 3. Protein content in rice samples from various brands.

3.5.3. Determination of fat content by using Soxhlet method

For analyzing the fat content, 1 g of each sample was placed in a porous thimble and the extracting solvent (150 mL of hexane) was placed in a dried, weighed distillation flask. The extraction was repeated continuously for a period of 1 h. The extracted fat presented in the distillation flask was dried in an oven at 100°C for 30 min. The flask was reweighted, and the increase in weight of the flask was taken as the weight of the fat present in the rice sample. **Table 4** lists the fat content for the ten different types of rice sample. The highest fat content was found in the Bird of Paradise rice (4.79%), and the lowest was Jasmine rice (3.0%). The average fat content for the 10 different types of rice samples was 3.65%. However, the fat content obtained in this analysis is slightly higher compared to the results obtained by Oko et al. [19] with the average fat content of 2.5 and 1.5%, respectively.

3.6. Rice trace element test

3.6.1. Chemicals and reagents

All chemicals and solvents were of analytical-reagent grade. Nickel(II) sulfate and chromium(III) chloride-6-hydrate were purchased from Hamburg Chemicals. Copper standard solution and calcium standard solution, magnesium sulfate heptahydrate and lead nitrate were purchased from Merck. Zinc chloride and cadmium nitrat-4-hydrate were purchased from Riedel-de Haen Chemicals. Nitric acid, perchloric acid and sulfuric acid were purchased from R & M chemicals.

3.6.2. Preparation of acid digested rice samples

One gram of each rice sample was accurately weighed in a sample container and transferred into a 250-mL conical flask. A mixture of concentrated acids containing nitric acid (67 mL),

Manufactured rice grain	Weight of round bottom flask (g)	Weight of round bottom flask and extracted fat (g)	Weight of sample (g)	Extracted fat (g)	Fat (%)
1. Maharaja Basmathi	95.2746	95.3135	1.0306	0.0377	3.77
2. SUMO Calrose	94.8465	94.8798	1.0001	0.0333	3.33
3. Jasmine Nutririce	94.8440	94.8747	1.0383	0.0307	3.00
4. Floral Glutinous	94.8337	94.8760	1.0004	0.0423	4.23
5. Sun Rise Australian Fragrant	95.2816	95.3184	1.0312	0.0368	3.57
6. Bird of Paradise	95.2751	95.3239	1.0185	0.0488	4.79
7. Phkarkhrrel Cambodi Organi	94.8476	94.8786	1.0235	0.0310	3.01
8. Sakura Super Thai	95.2832	95.3253	1.0150	0.0421	4.15
9. Sakura Super Pakistan	95.2675	95.3015	1.0002	0.0340	3.40
10. Giant Super Special Rice	95.2782	95.310	1.0225	0.0328	3.21

Table 4. Fat content in rice samples from various brands.

perchloric acid (22 mL) and sulfuric acid (13 mL) was added to each of the rice sample. The mixture was digested according to the wet digestion method [20] for 20 min at room temperature until a clear yellow solution was obtained. The digested rice samples were further digested with a reflux system for 40 min. The digested rice samples were allowed to cool down at room temperature for about 20 min until all the nitric fumes were evaporated. The digested rice samples were then boiled using a hot plate by increasing the temperature gradually until all perchloric fumes were evolved. The boiling process was stopped when a final volume of about 10 mL of clear liquid solution was obtained. The clear liquid solutions were then transferred into a 100-mL volumetric flask and topped up with deionized water. The concentration of trace elements in the rice samples was measured by using Shimadzu AA-6200 flame-AAS. Each analysis was conducted in triplicate, and the uncertainty in measurements was <10%.

3.6.3. Preparation of standard solutions

Stock solution (100 ppm) of a metal salt was prepared by dissolving appropriate amount of the metal salt with 20 mL of deionized water in 100-mL volumetric flasks. A mixture of acids containing nitric acid (5 mL), per chloric acid (1.7 mL) and sulfuric acid (0.8 mL) was added to the metal salt and topped up with deionized water to 100 mL. A series of standard solutions (2, 4, 6, 8, 10, 12, 14, and 16 ppm) were prepared by diluting from this stock solution and used to obtain the standard calibration curves. A blank standard solution containing same amount of concentrated acids but without rice sample was prepared as control.

3.6.4. Results and discussion

The results of trace element contents for 10 different types of rice sample are summarized in **Table 5**. These results indicated that the average content of Mg, Ca, Zn and Cu in the rice

Manufactured rice	**Trace element levels (mg kg^{-1})**							
	Mg	**Ca**	**Zn**	**Cu**	**Cr**	**Cd**	**Ni**	**Pb**
1. Maharaja Basmathi	23.0	9.0	10.0	9.0	nd	nd	nd	nd
2. SUMO Calrose	287.0	3.0	12.0	3.0	nd	nd	nd	nd
3. Jasmine Nutririce	42.0	14.0	18.0	14	nd	nd	nd	nd
4. Floral Glutinous	33.0	1.0	14.0	1.0	nd	nd	nd	nd
5. Sun Rise Australian Fragrant	31.0	6.0	14.0	6.0	nd	nd	nd	nd
6. Bird of Paradise Thai Fragrant	22.0	nd	9.0	nd	nd	nd	nd	nd
7. Phkarkhnei Cambodia Organi	35.0	13.0	13.0	13.0	nd	nd	nd	nd
8. Sakura Super Thai Brown Rice	29.0	10.0	11.0	10.0	nd	nd	nd	nd
9. Sakura Super Basmathi Pakistan	34.0	11.0	11.0	11.0	nd	nd	nd	nd
10. Giant Super Special White	91.0	8.0	11.0	8.0	nd	nd	nd	nd
Average value nd	62.7	8.3	12.3	7.5	nd	nd	nd	nd

nd = not detected

Table 5. Trace element levels for different types of rice sample.

samples was 62.7, 8.3, 12.3, 7.5 mg kg^{-1}, respectively, while the Cr, Cd, Ni and Pb were not detected. All the 10 different types of rice sample showed the highest average Mg content ranging from 22 to 287 mg kg^{-1}, followed by Zn (9–18 mg kg^{-1}), Ca (0–14 mg kg^{-1}) and Cu (0–14 mg kg^{-1}). Comparing the results in **Table 5** with the heavy metal content of rice samples from foreign countries, we found that there was not much difference in the heavy metal content between the two different sources. For example, the average Cd, Cr, Cu, Ni, Pb and Zn content in the rice samples from Taiwan was 0.02, 0.07, 2.20, 0.26, 0.01 and 14.6 mg kg^{-1}, respectively [21].

4. Conclusion

In this chapter, the emerging microwave and laboratory measurement techniques for rice processing and rice testing were presented. Up to 10 brands of manufactured rice grain in the market were analyzed in terms of physical and chemical properties. A wide range of microwave applications can be implemented in the rice industry. Besides microwave heating, the microwave technique used for rice insert control is considered new and attractive since this method leaves no chemical residues on the rice grain product. Microwave technology has provided a rapid and accurate measurement to test the quality of the rice in order to increase the rice production.

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References

[1] International Rice Research Institute (IRRI). Rice Quality. 2009. [Report]. Retrieved on November 24, 2012. Available from http://www.betuco.be/rijst/Rice%20Quality.pdf

[2] American Society of Agricultural and Biological Engineers (ASABE). ASAE S352.2 Moisture measurement – unground grain and seeds. 1998; St Joseph, MI, USA.

[3] Bhattacharya K R: Rice Quality: A Guide to Rice Properties and Analysis. New Delhi, India: Woodhead Publishing; 2011. ISBN: 9781845694852

[4] Yu X R, Su Y, Wang Y, Zheng T S, Zhao S M, Huang S Z: Study on microwave drying of grain. Proceedings of the 7th International Working Conference on Stored-product Protection.14-19 October. Beijing, China. 1998: 1096-1101.

[5] Abegaonkar M P, Karekar R N, Aiyer R C: A microwave microstrip ring resonator as a moisture sensor for biomaterials: application to wheat grains. Measurement Science Technology. 1999; **10(3)**: 195–200. doi:10.1088/0957-0233/10/3/014

[6] Kim K B, Kim J H, Lee S S, Noh S H: Measurement of grain moisture content using microwave attenuation at 10.5 GHz and moisture density. IEEE Transactions on Instrumentation and Measurement. 2002; **51(1)**: 72–77. doi:10.1109/19.989904

[7] Jafari F, Khalid K, Yusoff W M D W, Hassan J: The analysis and design of multi-layer microstrip moisture sensor for rice grain. Biosystem Engineering. 2010; **106(3)**: 324–331. doi:10.1016/j.biosystemseng.2010.04.005

[8] You K Y, Salleh J, Abbas Z, You L L: Cylindrical slot antennas for monitoring the quality of milled rice. Progress in Electromagnetics Research Symposium Proceedings. 12–16 September. Suzhou, China. 2011: 1370–1373.

[9] Mun H K, You K Y, Dimon M N: Rice grain moisture determination using microstrip wide-ring and microstrip coupled-line sensors. American Journal of Applied Sciences. 2015; **12(3)**: 112–120. doi:10.3844/ajassp.2015.112.120

[10] You K Y, Mun H K, You L L, Jamaliah S, Abbas Z: Small and slim coaxial probe for single rice grain moisture sensing. Sensors. 2013; **13(3)**: 3652–3663. doi:10.3390/s130303652

[11] Nelson S O: Dielectric properties of agricultural products – measurements and applications. IEEE Transactions on Electrical Insulation. 1991; **26(5)**: 845–869. doi:10.1109/14.99097

[12] Yadav B K, Jindal V K: Monitoring milling quality of rice by image analysis. *Computers* and Electronics in Agriculture. 2001; **33(1)**: 19–33. doi:10.1016/S0168-1699(01)00169-7

[13] Lloyd B J, Cnossen A G, Siebenmorgen T J: Evaluation of two methods for separating head rice from brokens for head rice yield determination. Applied Engineering in Agriculture. 2001; **17(5)**: 643–648. doi:10.13031/2013.6902

[14] Courtois F, Faessel M, Bonazzi C: Assessing breakage and cracks of parboiled rice kernels by image analysis techniques. Food Control. 2010; **21(4)**: 567–572. doi:10.1016/j.foodcont.2009.08.006

[15] Mun H K, You K Y, Dimon M N: Broken rice detection based on microwave measurement technique using microstrip wide-ring sensor and microstrip coupled-line sensor. Australian Journal of Crop Science. 2013; **7(13)**: 2079–2090. ISSN: 1835-2707[CE7]

[16] Nelson S O: Dielectric Properties of Agricultural Materials and Their Applications. U.S.: Elsevier; 2015. ISBN: 9780128023051.

[17] Deepa G, Singh V, Naidu K A: Nutrient composition and physiochemical properties of Indian medicinal rice–Njavara. Food Chemistry. 2008; **106**: 165–171.

[18] Kennedy G, Burlingame B: Analysis of food composition data on rice from a plant generic resources perspective. Food Chemistry. 2003; **80**: 589–596.

[19] Oko A O, Onyekwere S C: Studies on the proximate chemical composition, and mineral element contents of five new lowland rice varieties planed in Ebonyi State. International Journal of Biotechnology. 2010; **6**: 949–955.

[20] American Society for Testing and Materials (ASTM). Standard Guide for Preparation of Biological Samples for Inorganic Chemical Analysis, Water and Environmental Technology. Annual Book of ASTM standards. 2000; **11.01**, D 4638-95a. doi:10.1520/D4638-11

[21] Haw T L, Sue S W, Gwo C L: Heavy metal content of rice and shellfish in Taiwan. Journal of Food and Drug Analysis. 2004; **12(2)**: 167–174.