Infrared Spectroscopy and Morphological Assessments on the Nutritional Value of Prickly Pear Fruit

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Abstract The prickly pear fruit helps in combating viral based infections. It is used to treat diabetes and declared to possess hypoglycemic effects. There is also record of the usage of the fruit in the olden days as a remedy for diabetes，lipid disorders，inflammation，ulcers，and pharmacologic side effects. The chemical composition and nutritional values of skin，flesh and seed of prickly pear fruit were investigated and discussed on a dry weight situation. The infrared spectra as well as scanning electron microscopy (SEM) techniques were used to identify the functional groups of carbohydrates，amino acids，and protein. The infrared spectral data of all three (skin，flesh，and seeds) species were recorded and assigned to the presence of distinguish peaks that referred to the three different sugars (glucose，fructose and saccharose) and cyclic aliphatic hydrocarbons moieties. On the other hand，the SEM is a powerful tool to investigate the morphological features of the components. SEM assays were examined on the surfaces of skin，flesh and seed branches showing a small particle that tends to form clusters with different shapes compared to each other. The Energy-dispersive X-ray spectroscopy (EDX) is an analytical technique used for the elemental analysis or chemical characterization of a sample. The EDX spectral technique of the skin，flesh and seeds were confirmed the presence of different essential and useful elements such as carbon，oxygen，magnesium，calcium，potassium，sulfur，aluminum，silicon，chloride，and phosphorus.

Keywords Infrared spectroscopy；SEM；EDX；Prickly pear fruit；Skin；Flesh；Seed
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Introduction

Currently，only prickly pears are included in this genus of about 200 species distributed throughout most of the Americas[1]. Chollas are now separated into the genus Cylindropuntia，which some still consider a subgenus of Opuntia. Austrocylindropuntia，Corynopuntia and Micropuntia are also often included in the present genus，but like Cylindropuntia they seem rather well distinct. Brasiliopuntia and Miqueliopuntia are closer relatives of Opuntia.

The most commonly culinary species is the Indian Fig Opuntia (O. ficus-indica). Most culinary uses of the term "prickly pear" refer to this species. Prickly pears are also known as "tuna"，"nopal" or nopales，from the Nahuatl word nōpalli for the pads，or nostle，from the Nahuatl word nōchtli for the fruit；or paddle cactus (from the resemblance to the ball-and-paddle toy). This and similar species are native to Mexico. The genus is named for the Ancient Greek city of Opus[2].

In medical useful the most species of Opuntia contain a range of alkaloids in sample quantities，notably substituted phenethylamines. While the mere presence of such compounds has been confirmed in many species without further details[3]，they have been studied more thoroughly in others. Identified

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compounds of medical significance include 3-methoxytyramine[4], candicine[5], hordenine[6], N-methyltyramine[7], and tyramine[7]. The Sicilian prickly pear contains the betalain antioxidants betanin and indicaxanthin, with highest levels in their fruits[8].

1 Experimental

Infrared spectra within the range of 4 000～400 cm^{-1} for the skin, flesh and seeds of the cultivar 1 (sweetness, red, early ripening) and cultivar 2 (long fruit, green color, late ripening) were recorded from KBr discs using a Shimadzu FT-IR Spectrometer with 30 scans and 2 cm^{-1} resolution. Scanning electron microscopy (SEM) images and Energy Dispersive X-ray Detection (EDX) were taken in Joel JSM-6390 equipment, with an accelerating voltage of 20 kV.

2 Results and discussion

2.1 Infrared spectra

The infrared data for the skin (S), flesh (F) and seeds (K) of the cultivar 1 (sweetness, red, early ripening) and cultivar 2 (long fruit, green color, late ripening) are shown in Fig. 1 and the observed absorption bands were listed in Table 1. The band assignments between 4 000～400 cm^{-1} shows the main characteristic absorption bands of OH, CH_2, CH, and C═O groups. For example the ν(OH), $\nu(CH_2)+\nu$(CH), ν(C═O), δ(CH) and δ(OH) vibration of all cultivar 1 and cultivar 2 occurs at about 3 348～3 437, 2 942～

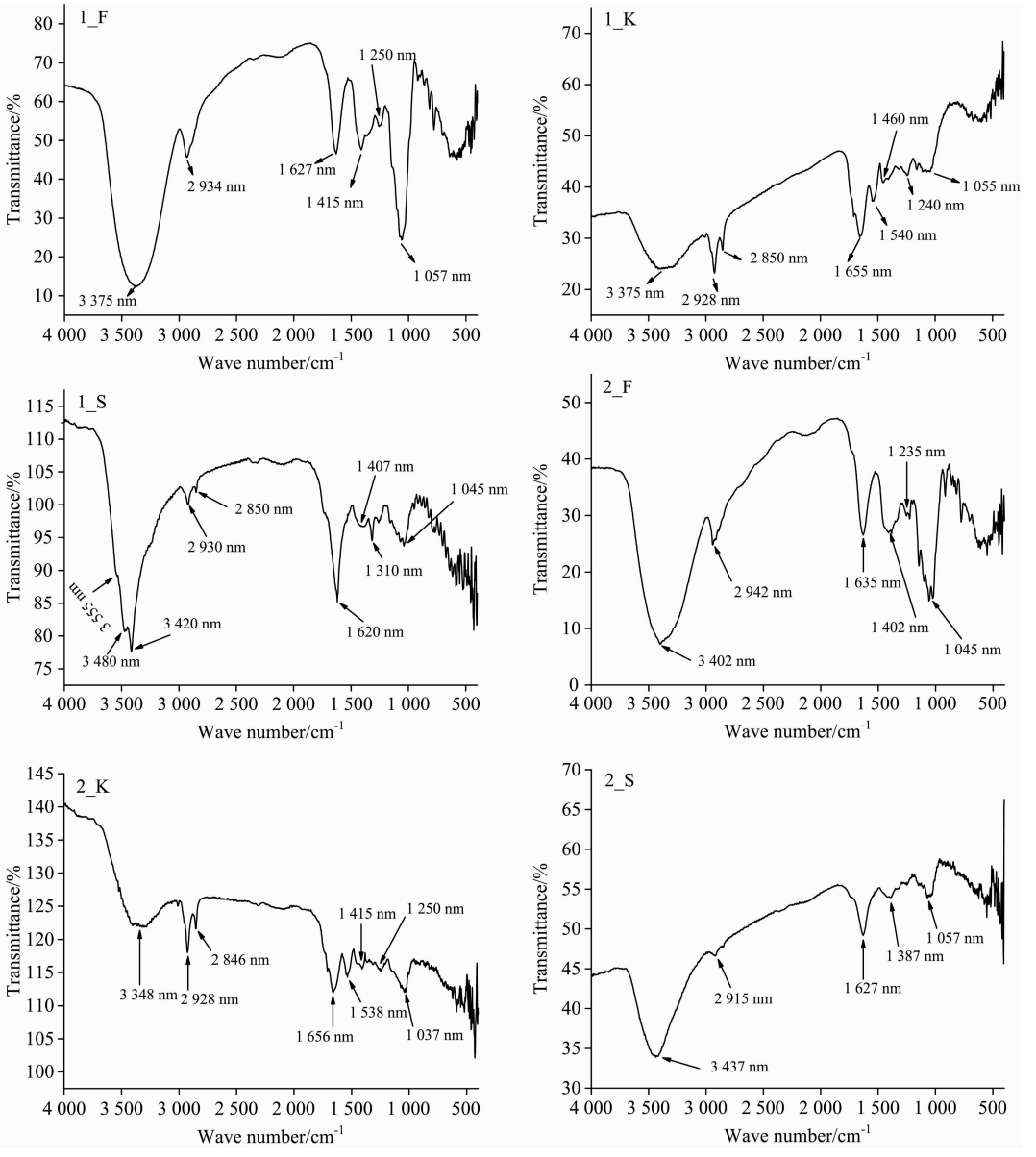


Fig. 1　Infrared spectra of skin (S), flesh (F) and seeds (K) of the cultivar 1 and cultivar

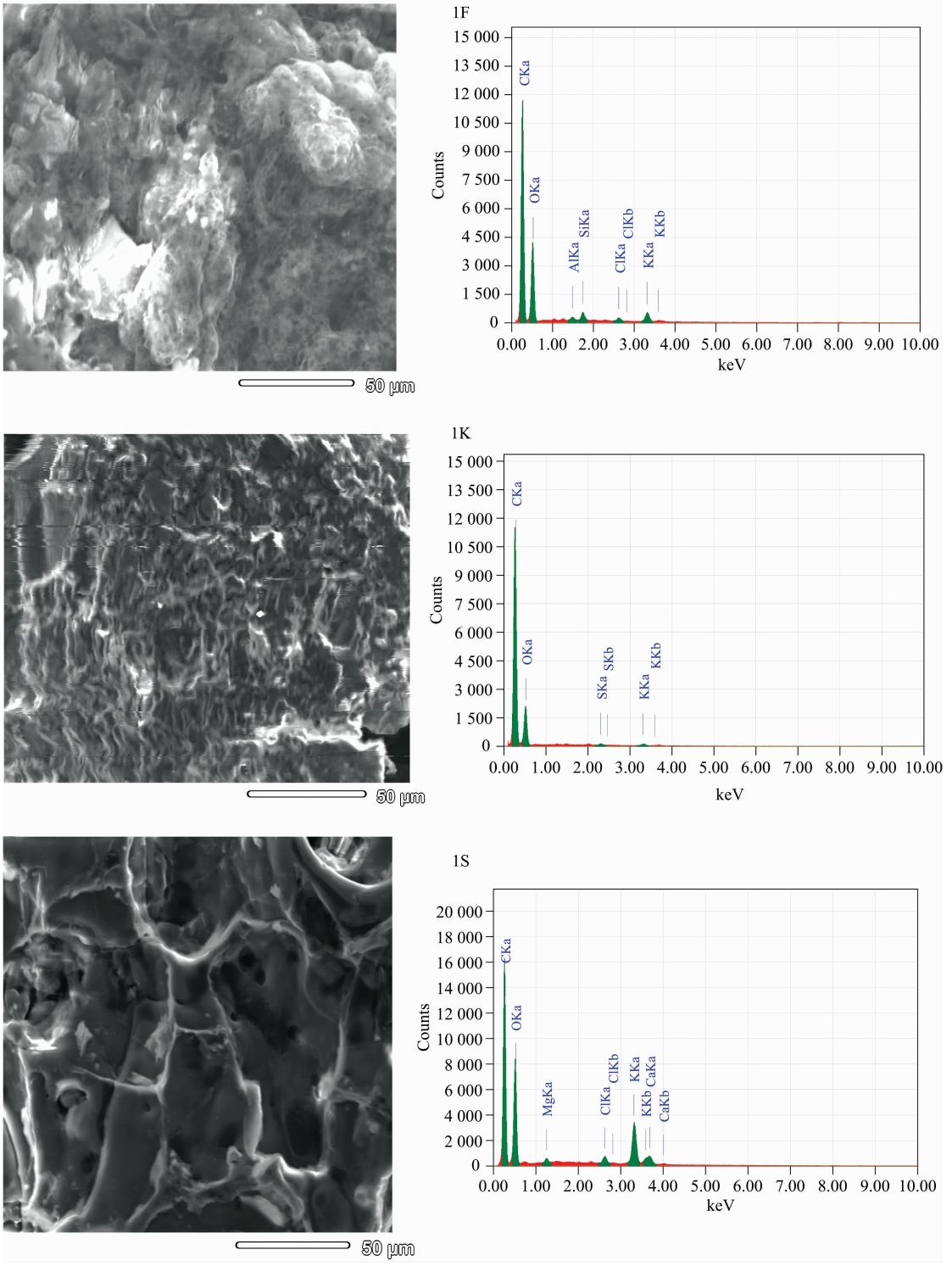
Table 1 Infrared spectral bands of skin (S), flesh (F) and seeds (K) of the cultivar 1 and cultivar 2

Samples	Infrared bands	Assignments	Suggested component
Flesh cultivar 1	3 375	ν(OH)	Glucose Fructose Saccharose
	2 934	$\nu(CH_2)+\nu$(CH)	
	1 627	ν(C═O)	
	1 415	δ(CH)	
	1 250	δ(OH)	
	1 057	δ(CH)	
Seeds cultivar 1	3 375	ν(OH)	Glucose Fructose Saccharose
	2 928+2 850	$\nu(CH_2)+\nu$(CH)	
	1 655	ν(C═O)	
	1 540+1 460	δ(CH)	
	1 240	δ(OH)	
	1 055	δ(CH)	
Skin cultivar 1	3 555+3 480+3 420	ν(OH)	Glucose Fructose Saccharose
	2 930+2 850	$\nu(CH_2)+\nu$(CH)	
	1 620	ν(C═O)	
	1 407+1 310	δ(OH)	
	1 045	δ(CH)	
Flesh cultivar 2	3 402	ν(OH)	Glucose Fructose Saccharose
	2 942	$\nu(CH_2)+\nu$(CH)	
	1 635	ν(C═O)	
	1 402	δ(CH)	
	1 235	δ(OH)	
	1 045	δ(CH)	
Seeds cultivar 2	3 348	ν(OH)	Glucose Fructose Saccharose
	2 928+2 846	$\nu(CH_2)+\nu$(CH)	
	1 656	ν(C═O)	
	1 538+1 415	δ(CH)	
	1 250	δ(OH)	
	1 037	δ(CH)	
Skin cultivar 2	3 437	ν(OH)	Glucose Fructose Saccharose
	2 915	$\nu(CH_2)+\nu$(CH)	
	1 627	ν(C═O)	
	1 387	δ(OH)	
	1 057	δ(CH)	

Table 2 EDX spectra of skin (S), flesh (F) and seeds (K) of the cultivar 1 and cultivar 2

Samples	Elements	Percentage/%	Samples	Elements	Percentage/%
Flesh cultivar 1	Carbon	55.22	Flesh cultivar 2	Carbon	51.36
	Oxygen	42.27		Oxygen	47.28
	Aluminum	0.28		Potassium	1.36
	Silicon	0.70			
	Chloride	0.34	Seeds cultivar 2	Carbon	59.11
	potassium	1.19		Oxygen	40.11
Seeds cultivar 1	Carbon	65.58		phosphorus	0.31
	Oxygen	33.92		potassium	0.47
	Sulfur	0.18			
	potassium	0.32	Skin cultivar 2	Carbon	41.13
Skin cultivar 1	Carbon	44.39		Oxygen	49.98
	Oxygen	48.28		Magnesium	0.78
	Magnesium	0.49		Chloride	1.02
	Chloride	0.68		Potassium	4.48
	Potassium	5.14			
	Calcium	1.01			

2 846, 1 656～1 620, 1 540～1 387 and 1 387～1 235 cm^{-1}, respectively. The presence of these bands confirmed that the all skin, flesh and seeds of the cultivar 1 and cultivar 2 contain carbohydrates with different structures like glucose, fructose and saccharose which contain mainly many groups of hydroxyl —OH, ketonic —C═O, aliphatic and cyclic aliphatic hydrocarbons[9].



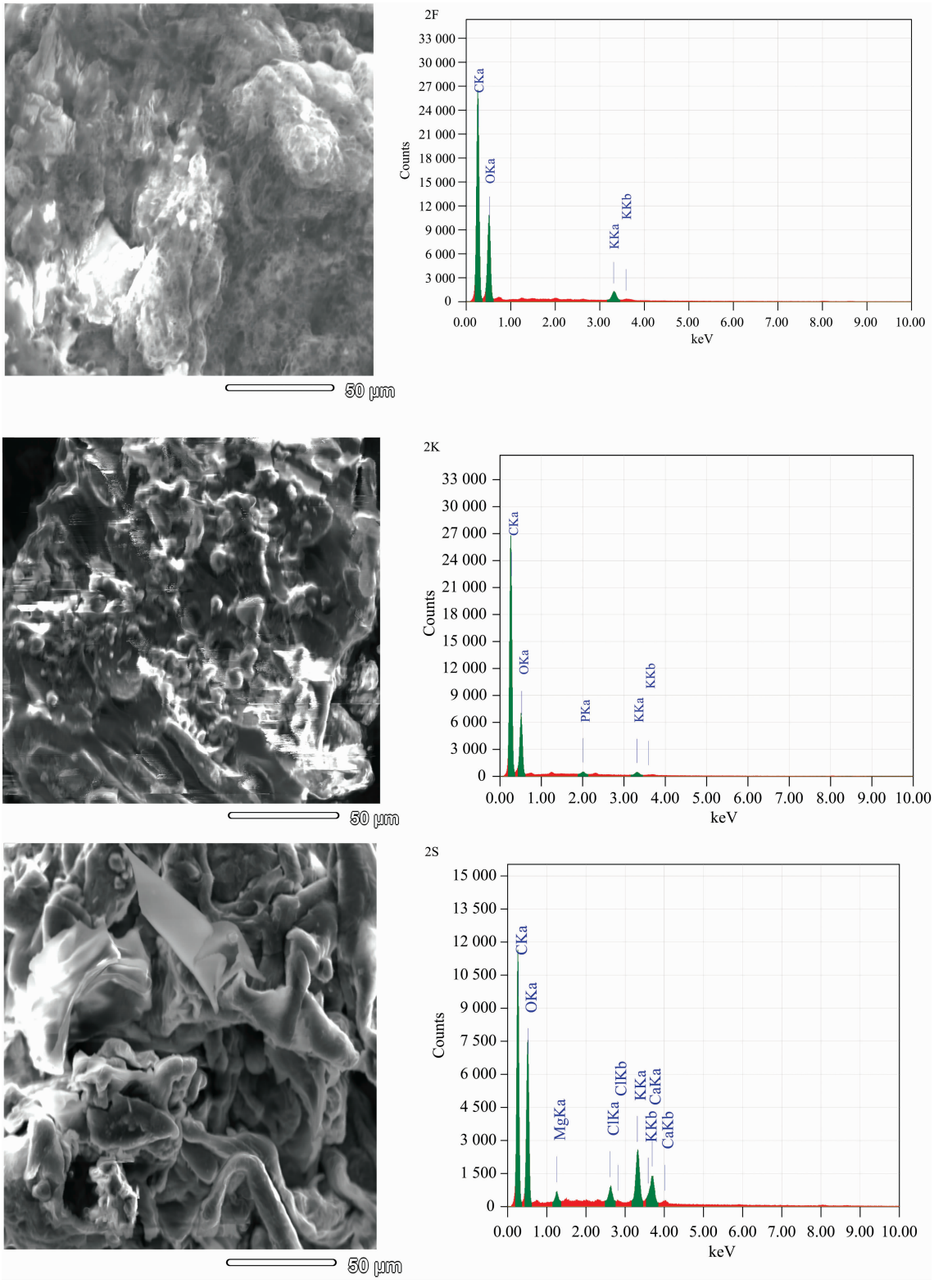


Fig. 2 SEM images and EDX spectra of skin (S), flesh (F) and seeds (K) of the cultivar 1 and cultivar 2

2.2 Scanning electron microscopes and EDX investigations

The chemical analysis results by EDX for the skin (S), flesh (F) and seeds (K) of the cultivar 1 and cultivar 2 showed that the skin, seeds and flesh of prickly pear fruit have a series of some metal salts like magnesium, potassium, aluminum and silicon with chlorides, sulfate or phosphates. The mineral composition depends on the fruit origin and factors of the site of cultivations[10]. SEM examinations were

checked the surfaces of these branches that show a small particle which tendency to agglomerates formation with different shapes comparison with each other. The chemical compositions of the skin (S) flesh (F) and seeds (K) of the cultivar 1 and cultivar 2 were determined using energy-dispersive X-ray diffraction (EDX). In the EDX profile of these branches (Fig. 2 and Table 2), the peaks of the carbon, oxygen, magnesium, calcium, potassium, sulfur, aluminum, silicon, chloride, and phosphorus elements, which constitute the molecules of skin, flesh and seeds of the cultivar 1 and cultivar 2, are clearly identified confirming the proposed structures.

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