IV. RESULTS AND DISCUSSION

The present investigation on processing of some fruits and their by-products included the study of the chemical and quality attributes for some fruits, bananas and guavas, grown in Egypt as well as the inedible or unutilizable parts left from their processing. Furthermore, the possibility of preparation of dehydrated products from these fruits at good quality and characterization of the produced dehydrated products after processing and after subsequent storage was also explored.

Data obtained throughout the course of the present investigation are presented and discussed under five subheadings as follows:

Part I: Bananas:

Preparation and characterization of fresh bananas and their dehydrated products.

Part II: Guavas:

Preparation and characterization of fresh guavas and their dehydrated products.

Part III: Inedible and processing residues of some fruits:

Characterization of by-products of processing ripe banana and guava fruits.

Part IV: Chromatographic analysis:

Characterization of fresh and their corresponding dehydrated fruits using gas chromatographic technique.

Part V : Technological applications:

Utilization of dehydrated products in preparation of some products.

Part I: Bananas.

4.1. Preparation and characterization of fresh bananas and their dehydrated product:

In Egypt, there is no direct processing of bananas although of the increase in its production and land productivity and thus, the subsequent decrease in its prices observed in the last few years. Banana was reported to be dehydrated by various methods such as sun-drying (Von-Loesecke, 1955); freeze-drying (Brekke and Allen, 1967; Okada and Quast ,1976); drum drying (Samish and Coussin, 1965; Brekke and Allen, 1967; Nur, 1976), vaccum oven-drying (Patil and Magar, 1976b, Adambounou and Castaigne,1983)solar dehydration (Pablo, 1979; Bowrey et al., 1989); spray drying (Patil and Magar, 1976b) as well as conventional air-forced drying methods (Bundus et al., 1964; Brekke and Allen, 1967; Rodriguez-Sosa et al., 1977; Andrade et al., 1980; Campbell and Campbell, 1983; Mowlah et al., 1983; Uzuegbu and Ukeka, 1987; Garcia et al., 1988). Furthermore, dehydration of bananas by osmosis using immersion in sugary syrup of solutions before drying either initially or eventionally or both, by freeze-drying, vacuum-drying or conventional air-drying was thoroughly investigated (Ponting et al., 1966; Brekke and Ponting, 1970; Hope and Vital, 1972; Garcia et al., 1974; Nur, 1976; Bongirwar and Sreenivasan, 1977; Ramamurthy et al., 1978; Ramanuja and Jayaraman, 1980; Dalla Rosa et al., 1982). The deep-frying of banana chips is another method for dehydration bananas which is stable for a year or more, where moisture content not exceeding 5%.

This part of study covers a comparative investigation on the suitability of the main banana cultivars grown in Egypt, i.e. Maghrabi, Paradica and Sindihi for processing into dehydrated products such as banana slices or rings and banana powder and also the establishment of optimum conditions for dehydrating these different cultivars. The obtained banana dehydrated products from the three cultivars were comparatively compared organoleptically, physically and chemically after dehydration and also after their subsequet storage in different containers for 6-9 months.

4.1.1. Establishment of optimum conditions for dehydrating banana fruits:

Processing treatments applied to fruits before dried are usually necessary to ensure a reasonably short drying time and to limit heat induced deteriorative changes to a minimum. The various predrying treatments, most of them are chemical means, ensure the production of dehydrated products of superior quality especially from the standpoint of change in colour.

Many workers have tried soaking treatment prior to dehydration for the purpose of inhibiting darkening and keeping out colour changes and promoting of colour after dehydration (Simon et al., 1955; Brekke and Allen, 1967; Tin Tin et al., 1969; Hope and Vital , 1972; Nur, 197 ; Madbouly, 1979; Maia et al., 1982). On the other hand, Campbell and Campbell (1983) indicated contrast attitude that pre-treatment of bananas, and some other fruits,before air-dehydration has certain advantages although they can be dried successfully without it.

The effect of various predrying treatments and also temperature of dehydration on colour of dehydrated banana pulp slices prepared from three well known cultivars grown in Egypt, i.e. Maghrabi, Paradica and Sindihi were investigated (Table 6). The predrying dipping solutions tested included citric acid (0.5, 1.0, 2.0% w/v), calcium chloride (0.1, 0.2, 0.3, 0.4, 0.5% w/v), sodium metabisulfite (1.0, 2.0% w/v) and ascorbic acid (1.0% w/v). These predrying treatments were compared for their efficiency in controlling of enzymatic and non enzymatic browning colour changes upon dehydrating banana slices uder two degrees of temperature (60°C or 80°C for the first 2 hours then finished at 60°C) for periods ranged from 6 to 18 hours.

4.1.1.1. Application of citric acid dipping solutions:

Several cut fruits, such as peachs, are often immersed in dilute solutions of acids such as citric acid because citric acid possesses a double inhibitory effect on phenolase (or polyphenol oxidase) enzymes not only by lowering the pH of the medium, but also by chelating with the copper moiety of the enzyme (Eskin *et al.*, 1971).

Dipping in citric acid solutions (1 or 2% for 2 or 4 min) before drying failed to improve colour of dehydrated Maghrabi and Paradica bananas where most dried samples at 60°C or at 80°C treatment (80°C for the first 2 hours then finished at 60°C) had fair colour scores which did not exceed

Table 6 : Effect of various dipping treatments and temperature of dehydration on colour of dehydrated banana pulp slices prepared from three banana cultivars grown in Egypt.

Soaking or dipping treatment	Banana Cultivar: Maghrabi — Temperature of dehydration (60°C)	Paradica (60°C)	Sindihi (60°C)	Maghrabi — Temperature of dehydration (80°C for 2 hr then finished at 60°C)	Paradica (80°C for 2 hr then finished at 60°C)	Sindihi (80°C for 2 hr then finished at 60°C)
I. Dipping in citric acid solutions						
1. Control (no treatment)	F[1]	F	G[2]	F	F	G
2. 1% citric acid for 2 min.	F	F	G	F	F	G
3. 1% citric acid for 4 min.	F	F	G	F	F	G
4. 2% citric acid for 2 min.	F	F	G	F	F	G
5. 2% citric acid for 4 min.	F	F	G	F	F	G
II. Soaking during peeling process in 0.5%, citric acid followed by another dipping treatments						
6. Control (no treatment)	F	F	G	F	F	G
7. 1% $Na_2S_2O_5$ for 3 min.	F	F	G	F	F	G
8. 2% $Na_2S_2O_5$ for 3 min.	F	F	G	G	G	G
9. 1% $Na_2S_2O_5$ + 0.3% $CaCl_2$ for 3 min.	F	F	G	F	F	G
10. 1% $Na_2S_2O_5$ + 0.4% $CaCl_2$ for 3 min.	F	F	G	F	F	G
11. 1% $Na_2S_2O_5$ + 1% ascorbic acid for 3 min.	F	F	G	F	F	G
III. No treatment at peeling time before dipping in various chemical solutions						
12. Control (no treatment)	F	F	G	F	F	G
13. 1% $Na_2S_2O_5$ for 3 min.	G	G	G	G	G	E[3]
14. 2% $Na_2S_2O_5$ for 3 min.	G	G	G	G	G	E
15. 1% $Na_2S_2O_5$ + 1% ascorbic acid for 3 min.	G	G	G	G	G	G
16. 1% $Na_2S_2O_5$ + 1% $CaCl_2$ for 3 min.	G	G	G	G	G	E
17. 1% $Na_2S_2O_5$ + 0.2% $CaCl_2$ for 3 min.	G	G	G	E	E	E
18. 1% $Na_2S_2O_5$ + 0.3% $CaCl_2$ for 3 min.	E	E	E	E	E	E
19. 1% $Na_2S_2O_5$ + 0.4% $CaCl_2$ for 3 min.	E	E	E	E	E	E
20. 1% $Na_2S_2O_5$ + 0.5% $CaCl_2$ for 3 min.	E	E	E	E	E	E
IV. Blanching treatment						
21. Control (no treatment)	F	F	G	F	F	F
22. Blancing in boiling water (with peel) for 3 min.	F	F	F	F	F	F

1. Fair 2. Good 3. Excellent

those scores given to the corresponding control samples dried at both degrees of dehydration temperature. Moreover, such dipping step did not provide any promising effect on colour of dehydrated Sindihi banana since this treatment resulted in good colour scores upon drying Sindihi bananas at both temperatures tested which did not differ from those scores given to their corresponding control samples (Table 6).

In addition, soaking in 0.5%citric acid during peeling time (about 5 min.) followed by dipping in either of the various solutions utilized did not improve colour of different dehydrated bananas upon drying at either of 60°C or 80°C treatments.

From the standpoint of colour of dehydrated banana pulp, results of the application of citric acid before dipping in the various solutions tested did not differ from those obtained upon soaking bananas in only 0.5% citric acid before their dehydration. The only exception was for Maghrabi and Paradica bananas dipped in citric acid followed by soaking in 2% $Na_2S_2O_5$ for 3 min before drying at 80°C treatment (but not 60°C) where they had good colour scores which were higher than those for their corresponding control treatments (Table 6).

Although citric acid, separately or in conjunction with ascorbic acid or sodium sulfite, has long been used as a chemical inhibitor of enzymic browning (Joslyn and Ponting, 1951; Ponting, 1960; Schwimmer and Burr, 1967), results of the present study indicates that citric acid (at the concentrations applied) was not effective in maintaining colour of dehydrated bananas. In partial agreement of our finding, Eskin et al. (1971) stated that citric acid on its own is not too effective as a phenolase (or PPO) inhibitor.

In contrast to our findings, Madbouly (1979) recommended that the best treatment for optimum colour value of dehydrated banana of Egyptian cultivars was 0.2% citric acid + 1% ascorbic acid. Moreover, Uzuegbu and Ukeka (1987) prepared successfully sun-dried and cabient dehydrated green and full-ripe bananas using citric acid pretreatment to decrease pH to 3.3.

4.1.1.2. Application of sodium metabisulfite in the predrying dip solution:

Sulfite salts are conventient form of sulfur dioxide for treating dehydrated fruits and vegetables to preserve colour and also inhibit microorganism. When dissolved in water the sulfites form sulfurous acid, the bisulfite ion and the sulfite ion, the relative proportion of each form depends on pH of solution (Shallenberger and Jansen, 1977).

Soaking Maghrabi and Paradica banana pulps in solutions of 1 and 2 % $Na_2S_2O_5$ for 3 min before dehydration resulted in dehydrated slices of good colour scores upon drying at either 60°C or at 80°C treatment which represented higher scores than those obtained with their corresponding controls (fair scores).

Although, soaking in 1 or 2% $Na_2S_2O_5$ for 3 min did not improve the colour scores of Sindihi banana dehydrated at 60°C, which were not different than those obtained for their corresponding controls, Sindihi banana dehydrated using 80°C treatment exhibited excellent colour scores which were higher than those given for their corresponding dried control bananas. It was noticed that the increase in concentration of $Na_2S_2O_5$ more than 1% did not improve the colour of dehydrated bananas of all cultivars tested.

In agreement of our results, Tin Tin et al. (1969) dipped banana in sodium metabisulfite and dehydrated it at 70-80°C. The fruits retained their colour and flavour with 1% sodium metabisulfite and had no So_2 aftertaste. Brekke and Allen (1967) as well as Uzuegbu and Ukeka (1987) employed 1% of either sodium bisulfites or potassium metabisulfite, respectively, during air-dehydration and osmotic dehydration of bananas, respectively.

The concentration used in the present study is higher than that used by Ramamurthy et al. (1978) who found that dipping in 0.25% sodium metabisulfite for 10-15 min at room temperature followed by soaking in 70% sugars syrup at 50°C for 3 hours before dehydration produced best quality.

The obtained result is in contrast to those of Madbouly (1979) that the best pretreatment for air dehydrated banana prepared from Egyptian cultivar was that of 0.2% citric acid + 1% ascorbic acid which was better than the sulfured treatment

(1% NaH So_3) from the standpoint of colour value (Methanol-extracted colour).

4.1.1.3. Application of sodium metabisulfite in conjunction with ascorbic acid in the predrying dip solutions :

Since $Na_2S_2O_5$ dip was not able to provide excellent colour scores for all dehydrated bananas of the cultivars tested, even at 2% concentration, experiments were undertaken to test the effect of adding ascorbic acid to $Na_2S_2O_5$ in the dip solutions before dehydrating pulps of the three banana cultivars.

Ascorbic acid was reported to be a significant potent inhibitor of PPO enzyme and thus enzymic browning (Taeuful and Voigt, 1964). It does not have any detectable odour, it does not have any corrosive action and,in addition, its vitamin value is well known. Ascorbic acid is a very effective reducing agent and as such reduces the o-quinones formed by polyphenol oxidase enzymes to the original o-dihydroxy phenolic compounds and thus the reactions of o-quinones which lead to the formation of brown substances can be prevented by ascorbic acid (Sallenberger and Jansen, 1977).

Under the conditions of the present study,soaking sliced pulps of bananas from the three tested cultivars in solution of 1% $Na_2S_2O_5$ + 1% ascorbic acid for 3 min gave colour scores which did not differ from those obtained for dehydrated bananas previously soaked in only 1% $Na_2S_2O_5$ solutions.

Probably the reason of the ineffectiveness of ascorbic acid in producing superior colour score for dehydrated bananas under conditions of the present study was its lower concentration used in the pre-drying dip solution. Eskin et al. (1971) stated that browning in fruits is effectively prevented by the generous application of excess ascorbic acid and that the presence of dissolved oxygen increase the possibility of auto-oxidation of ascorbic acid and thus oxygen become the limiting factor in determining the rate of enzymic browning.

4.1.1.4. Application of blanching pretreatment before dehydration:

Several workers reported that blanching of some fruits would improve the dehydrated products;and banana fruits are not an exception. However, results of the present study demonstrated that blanching bananas in boiling water (with peel) for 3 min did not improve the colour of dehydrated pulp, regardless of the kind of banana cultivars used, where colour scores for dehydrated blanched bananas did not differ from those obtained by the unblanched controls and even worse than those recorded for their corresponding controls in case of Sindihi bananas.

In contrast to our results, a reported on drum-drying banana puree in Israel (Samish and Coussin, 1965) showed that steam blanching prior to drying improved the product colour and that the addition of So_2 improved further the colour. Moreover, Luh and Palmer (1975, 1976) indicated that steam blanching at 50-65°C of sliced banana was effective in preventing discolouration when dehydrated until moisture was reduced to 20%.

4.1.1.5. Application of sodium metabisulfite in conjunction with calcium chloride in the predrying dip solutions:

Since either the application of $Na_2S_2O_4$ alone or in conjunction of 1% ascorbic acid did not provide superior colour scores for all dehydrated bananas,the effect of adding 0.1, 0.2, 0.3, 0.4 and 0.5% calcium chloride to 1% $Na_2S_2O_4$ in the predrying dip solution was tested.

Calcium chloride was reported by Simon et al. (1955) to be a possible inhibitor of browning and suggested that its inhibitory effect was due to the chleation of calcium with amino acids. Calcium chloride treatment has been shown to retard browning in many vegetables and also fruits after dehydration and also subsequent storage, especially in case of pears (Zerbini and Sozzi, 1981) and in apples (Petriella et al., 1985; Drake and Fridlund, 1986).

The substitution of ascorbic acid for $CaCl_2$ in solutions of 1% $Na_2S_2O_5$ certainly improved the colour of dehydrated bananas regardless of dehydration temperature used. Soaking in solutions of 1% $Na_2S_2O_5$ + 0.I or 0.2% $CaCl_2$ for 3 min before dehydration produced a good colour score for all banana cultivars dried at 60°C. Upon dehydration with 80°C treatment the increase of $CaCl_2$ concentration from 0.1 to 0.2% in the 1% $Na_2S_2O_5$ solution improved greatly the colour of dehydrated Maghrabi and Paradica slices. Soaking Sindihi sliced pulp in either 0.1 or 0.2% $CaCl_2$ + 1% $Na_2S_2O_5$ led to dehydrated bananas of excellent score upon drying with 80°C treatment. The increase in concentration of $CaCl_2$ more than 0.3% in the 1% $Na_2S_2O_5$ solution resulted in consistent colour scores (excellent) for dehydrated bananas dried at either 60 or 80°C treatment, regardless of the kind of starting banana cultivar.

In agreement to our results, Bolin and Steele (1987) stated that 0.5 to 1.0% $CaCl_2$ treatment dip for apples resulted in remaining light longer during storage and reduced rate of darkening during storage of dried apples for two months. They stated that the progressive increase in $CaCl_2$ from 0.5 up to 5% in dip solutions caused increase in calcium level and in pH in dry products which darkened progressively faster upon storage. Moreover, Brekke and Allen (1967); Tin Tin (1969); Maia et al. (1982) stated that treatment of banana by SO_2 before dehydration of air-forced, drum and freeze-drying enhanced the quality of all products significantly.

4.1.1.6. Concluding remarks on optimum predrying treatment and dehydration conditions:

From the above mentioned data it could be concluded that soaking in 1% $Na_2S_2O_5$ together with $CaCl_2$ (0.3 or 0.4 or 0.5%) produced an excellent and acceptable colour for bananas dehydrated at either 60°C or 80°C treatments. Furthermore, it was clearly noticed that Sindihi bananas showed dehydrated material of better colour than those of Maghrabi and Paradica bananas with most of the predrying soaking treatments. Another finding was noted was that the successful dehydration of banana pulp slices dependent on temperature of dehydration and concentration of various solutions in the predrying soaking treatments.

The period required for complete drying varied greatly with the three banana cultivars and also with the temperature system applied. Sliced pulp of Maghrabi, Paradica and Sindihi reached constant weight (moisture content between

4.3 to 7.0%) after 18, 14 and 8 hrs at 60°C as well as 16, 12 and 6 hrs at the 80°C treatment (80°C for the first 2 hrs, then finished at 60°C) respectively. Besides the superior colour scores after dehydration, it is apparent that dehydration of Sindihi was remarkedly more economic than the other two cultivars from the standpoint of energy consumption, moisture content and time required to reach complete dryness (about 4.3 to 4.6% moisture content).

The difference between the three bananas cultivars with regard to the effect of predrying treatments and also dehydration conditions could be attributed to the variation in their physical and chemical properties before drying. Furthermore, Olorunda _et al_. (1977) stated that flavour and reheology of dehydrated banana before and after storage was influenced greatly by pre-ripening treatments.

The best dehydration temperature reported for drying bananas by different investigators are not different from these used in the present study. Maia _et al_. (1982) dehydrated Brazilian cultivars of bananas by air-forced method at 70°C while Asiedu (1987) stated that the most suitable temperature for drying unripe and ripe bananas or plantain was 50 to 70°C. Uzuegba and Ukeka (1987) used 71.1°C for 1 hr followed by 93.3°C for 5 hrs as well as 93.3°C for 6 hrs for dehydrating green or fully rip bananas.

The temperature used in the present study is not different from that used upon applying osmotic dehydration employing immersion in sucrose syrup or corn syrup (60-70% solutions) followed by lower dehydration temperature of 50°C (Nur, 1976; Bangirwar and Sreenivasan,1977) or 60°C for 4 hrs (Garcia, _et al_., 1974) or 60°C ± 2 for 8 hrs under pressure

(Ramamurthy *et al.*, 1978) and of 65°C under vacuum (Adambounou and Castaigne, 1983). However, the system of dehydration applied in the present study provided good properties for dehydration products with such a conventional method. Osmotic drying processes were reported to be more expensive than conventional method due to higher capital expenses (Garcia *et al.*, 1974).

4.1.2. Comparative characterization of fresh starting bananas and their dehydrated products:

Data collected from experiments conducted to select optimum predrying treatments,depending on colour of dehydrated banana materials,indicated that only three pre-treatments produced the maximum colour scores. Therefore, it was decided to prepare different dehydrated bananas from ripe pulps of the three cultivars tested i.e. Maghrabi, Paradica and Sindihi using these three best pretreatments.

The three pretreatments included the application, in a comparative way, solutions of 1% $Na_2S_2O_5$ + 0.3% $CaCl_2$; 1% $Na_2S_2O_5$ + 0.4% $CaCl_2$ and 1% $Na_2S_2O_5$ + 1% ascorbic acid for 3 min followed by dehydration at 80°C for the first 2 hours then finished at 60°C until constant weight (6-16 hours). In addition to the three tested treatments for each banana cultivar another one was added which employed sliced bananas not receiving any pre-treatment before dehydration at the same conditions applied for the other three pre-treated groups and thus, served as non-treatment control.

The four dehydrated products prepared from ripe pulps of each banana cultivar tested were then comparatively evaluated for their drying ratioes, organoleptic properties, rehydration characteristics as well as their chemical constituents such as moisture content, crude protein, ether extract, ash, total carbohydrates, total reducing and non-reducing sugars, starch, total pectic substances and distribution of their fractions, pigments, phenols, ascorbic acid, residual sulphur dioxide, serum colour, mineral contents and enzymatic activities as well as their microbial load.

4.1.2.1. Dehydration yield and ratio of drying:

As shown in Table (55) estimation of yield of dehydrated products (weight of finished product / weight of whole bananas) indicated that maximum yield was obtained from Paradica banana (24.87%). Paradica provided higher yield than both Sindihi (21.35%) and Maghrabi (19.57%). On the other hand, practical yield of dehydrated banana, (weight of finished product/weight of pulp only excluding peels) indicated that maximum yield was obtained with Sindihi and Paradica which showed comparable yield (34.96 and 34.72%, respectively) while the smallest yield was obtained with Maghrabi bananas (28.41%).

The obtained data for yield are higher than those calculated by Maia *et al*. (1982) for bananas of two Brazilian cultivars which had yield (whole, with peels) of 15.70 and 15.10% upon dehydration up to moisture content 25.6 and 13.92%, respectively, at 70°C temperature for 18 hours and also the yield reported by Von Loesecke (1955) of only 13% (whole, with peels).

Dehydration ratioes were found to differ according to percentage of moisture content before and after processing and also with predrying treatment applied before dehydration (Table 11). However, dehydrated treatment of Maghrabi banana showed higher drying ratioes (between 3.50:1 to 3.55:1) than Paradica (between 2.86:1 to 2.91:1) and Sindihi (between 2.84:1 to 2.87:1) depending on pretreatment before drying and variations in moisture content. Untreated dehydrated control had higher drying ratio than the treated ones, while treatment I and II showed comparable drying ratioes (Table 11).

4.1.2.2. Sensory and organoleptic properties of dehydrated products:

Treated dehydrated Sindihi banana slices and also powders were found to have better colour and texture scores than those given to non-treated control samples while flavour scores for non-treated control were superior to those given to treated dehydrated bananas (Table 7).

The flavour of the air-dried slices differed distinctly from that of fresh bananas, but was unmistakenly banana like, the unsulfured products (control) resembled fresh banana more closely than did the sulfured one (treatment I and II).

Dehydrated slices and powders of Sindihi bananas prepared using treatment II were more acceptable and exhibited higher colour and texture scores than those for the non-treated control and treatment I.

Preliminary sensory evaluation indicated that all Sindihi dehydrated banana treatments were more acceptable and superior from the point of colour and texture to other treatments prepared from either Maghrabi and Paradica. Maghrabi was only superior to both Sindihi and Paradica in flavour. Furthermore, Maghrabi had better bright colour than Paradica dry products,

Table 7 : Sensory evaluation of reconstituted dehydrated banana pulp slices and powders prepared from Sindihi cultivar using different treatment.

	Organoleptic scores					
	Dehydrated sliced			Dehydrated powder		
	Control[1]	Treatment I[2]	Treatment II[3]	Control[1]	Treat.I[2]	Treat.II[3]
Colour (10)	7.0	7.5	7.7	7.0	7.5	7.7
Flavour (10)	5.5	5.1	5.0	5.5	5.1	5.0
Texture (10)	7.8	8.3	8.9	7.8	8.3	8.9

1. Dehydrated sliced pulp (without any treatment).
2. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 0.3% $CaCl_2$ for 3 min before dehydration.
3. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 0.4% $CaCl_2$ for 3 min before dehydration.

During the course of preparation of powder from dehydrated banana slices (immediately after drying) dry Sindihi slices were the easiest to grind and to disperse while those of Maghrabi were the worst since they tended to stick during grinding and afterwords upon standing at room temperature. However, Paradica slices were more easier to grind than Maghrabi dry slices.

In contrast to our data, Madbouly (1979) indicated that organoleptic scores for dehydrated Hindi banana cultivar grown in Egypt were superior for citric acid + ascorbic acid treatment than the sulfured treatment especially in flavour scores while both treated banana had comparable colour scores which were higher than those for the untreated sample.

4.1.2.3. Rehydration properties of dry banana slices:

The rehydration ratio, coefficient of rehydration and moisture content (%) in rehydrated samples were determined for the tested samples at various time intervals for a total period of 3 hrs of soaking in water at room temperature and the obtained results are shown in Table 8. The rehydration ratio, coefficient of rehydration and moisture content (%) in rehydrated samples showed variation in their values in function of previous treatment before dehydration, where they ranged between 1:2.5 to 1:2.8, 0.87 to 0.98 and between 61.64 to 65.93%, respectively, after soaking in water for 1 hour, and ranged between 1:3.0 to 1:3.4, 1.04 to 1.18 and between 67.97 to 71.80%, respectively, as a result of extending the soaking periods for 3 hrs under the same soaking conditions.

Table 8 : Rehydration characteristics of dehydrated banana pulp slices prepared from Sindihi cultivar.

Rehydration properties	hr	Control[1]	Treatment I[2]	Treatment II[3]
Rehydration ratio	1	1:2.8	1:2.6	1:2.5
	2	1:3.2	1:2.7	1:2.8
	3	1:3.4	1:3.2	1:3.0
Coefficient of rehydration	1	0.98	0.91	0.87
	2	1.12	0.96	0.96
	3	1.18	1.11	1.04
Moisture content % in rehydrated sample	1	65.93	63.25	61.64
	2	70.17	65.27	65.40
	3	71.80	69.90	67.97

1. Dehydrated sliced pulp (without any treatment).
2. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 0.3% $CaCl_2$ for 3 min before dehydration.
3. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 0.4% $CaCl_2$ for 3 min before dehydration.

Non-treatment control sample showed a higher rehydration ratio, coefficient of rehydration and moisture content(%) in rehydrated sample than that of treatment I and II, respectively, by about 6.25 and 13.33%; 5.93 and 13.46%; 2.72 and 5.63%, respectively. This means that chemical pre-drying treatment and its concentration had a negative influence on rehydration properties.

The observed differences in rehydration properties between the various treatments could be attributed to the fact at there are many factors which influence the dehydrated products and, therefore, their subsequent rehydration although rehydration is not the opposite of dehydration (Morton and Waston, 1988). The loss of osmotic properties and differential permeability in the protoplasmic membrane and the increase in crystallisation of polysaccharides gels in the cell wall as well as the coagulation of protoplasmic proteins occurred as a result of dehydration play a key role in the changes in texture and rehydration capability that occur after any given food samples that have been dehydrated (Shimazu and Sterling, 1961; Karel, 1974 ; DeMan, 1976).

The initial rate of rehydration involves mainly the amorphous regions, which present the most accessible surface to the rehydration medium. The difference in rehydration that occurs between different dehydrated fruits and vegetables probably depends upon the hydrolysis of the polysaccharides, such as hemicelluloses and pectienates during dehydration. (Saad, 1989

The hydrolysis of the hemicelluloses, the pectienates and the amorphous regions of the cellulose molecules is usually catalysed by hydrogen ions. In the hydrolysis of these polysaccharides,the acetal bonds between the sugar residues are usually broken and water molecules are added to the polysaccharide molecules at the place of this breakage (Nikitin, 1966). The lower amount of rehydration is subsequently a result of the lesser amount of hydrogen ion present to catalyse the hydrolysis (Horn and Sterling,1982).

Furthermore, numerous predrying treatments and additives and better packaging also have contributed to the rehydration characteristics of many dried products (Neumann, 1972). For example, the high loss occurred in soluble solids during pretreatment was though to be responsible for improved rehydration (Neumann, 1972).

The pH and ionic salts was reported to influence rehydration properties since they affect cell wall permeability to water (Neumann, 1972).

Predrying treatments with sodium carbonate, sodium bisulfite, and/or 60% sucrose at ambient temperature, separately or in various combinations, produced distinct differences in rehydration characteristics and appearance of dehydrated vegetables (Neumann, 1972).

4.1.2.4. Proximate chemical composition:

A) Ripe pulps of fresh starting bananas from different cultivars:

Fresh ripe pulps of Maghrabi, Paradica and Sindihi bananas as well as their dehydrated materials were analysed chemically for their content in moisture, crude protein, ether extract , ash,total carbohydrates and crude fiber (Table 9).

The obtained data indicated that carbohydrates constituted the major component in fresh pulps of the three banana cultivars grown in Egypt. Ash was the second principal component in fresh pulp of Maghrabi (3.85%) and Sindihi (2.87 %), while crude protein formed the second component in Paradica (2.65%). However, crude protein ranked the third component in Maghrabi (3.66%) and Sindihi (2.14%) while ash formed the third component in Paradica (2.3%). Ether extract ranked the fourth with all banana cultivars under investigation.

The three banana cultivars showed some variation in their contents of ash, crude protein, ether extract and crude fibers. In contrast, carbohydrates content did not differ significantly with cultivar kind which ranged between (92.07-94.55%). Fresh ripe pulp of Maghrabi cultivar, in particular, exhibited the highest content in moisture, crude protein, ash and crude fibers (73.42, 3.66, 3.85 and 1.56%, respectively), but the lowest content in total carbohydrates and ether extract (92.07 and 0.42%, respectively) compared to other bananas cultivars tested.

Fresh pulp of Sindihi cultivar showed the highest content in ether extract (0.72%), but the lowest content in crude

Table 9 : Proximate chemical analysis of fresh banana pulp before and after dehydration into dry powder prepared from three banana cultivars grown in Egypt using different treatments (g/100 g dry weight basis).

Analysis[1]	Banana cultivar: Maghrabi					Banana cultivar: Paradica					Banana cultivar: Sindihi				
	Fresh pulp	Control[2]	Treat-ment I[3]	Treat-ment II[4]	Treat-ment III[5]	Fresh pulp	Control[2]	Treat-ment I[3]	Treat-ment II[4]	Treat-ment III[5]	Fresh pulp	Control[2]	Treat-ment I[3]	Treat-ment II[4]	Treat-ment III[5]
Crude protein (Nx6.25)	3.66	3.64	3.63	3.63	3.64	2.65	2.63	2.62	2.62	2.63	2.16	2.14	2.12	2.12	2.13
Ether extract	0.42	0.41	0.40	0.40	0.41	0.50	0.49	0.48	0.48	0.49	0.72	0.71	0.71	0.70	0.71
Ash	3.85	3.87	3.96	4.00	3.93	2.30	2.33	2.40	2.42	2.37	2.87	2.89	2.96	3.00	2.93
Total carbohydrates (by difference)	92.07	92.08	92.01	91.97	92.02	94.55	94.55	94.50	94.48	94.51	94.25	94.26	94.22	94.18	94.23
- Crude fiber	1.56	1.58	1.55	1.55	1.56	1.50	1.52	1.48	1.49	1.49	1.16	1.17	1.15	1.15	1.16
Moisture content	73.42	5.63	6.42	6.35	6.99	67.39	5.25	6.55	6.35	6.62	66.66	4.26	5.18	4.86	5.65

1. Average of duplicate analysis,
2. Dehydrated sliced pulp (without any treatment).
3. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 0.3% $CaCl_2$ for 3 min before dehydration,
4. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 0.4% $CaCl_2$ for 3 min before dehydration,
5. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 1% ascorbic acid for 3 min before dehydration.

protein and crude fibers(2.16 and 1.16%, respectively) compared to other bananas cultivars. Fresh pulp of Paradica cultivar had the highest content in total carbohydrates (94.55%) but the lowest content in ash (2.30%) compared to other bananas cultivars.

Data obtained are in general agreement with those found by Madbouly (1979); Sharaf et al. (1971) and Saad (1989) for banana cultivars grown in Egypt, as well as those by Kayisu et al. (1981) and Izonfuo and Omauru (1988) for different banana varieties grown in Zaire and Nigeria, respectively, and by Barthakur and Arnold (1990) for Musa Bhimkol bananas. grown in India.

B) Dehydrated banana products:

Moisture content of all dehydrated banana products ranged between 4.3 to 6.99%.The highest moisture content was found in those prepared from Maghrabi cultivar, while the lowest content was found in Sindihi dry products. Although no difference in method of dehydration existed, the obtained values for moisture content are much lowder than those reported by Madbouly (1979) for dehydrated Egyptian"Hindi"bananas (16.45 to 17.46) upon oven drying at 80°C for 9-10 hrs) and also lower than those reported by Brekke and Allen (1967) and Maia et al. (1982) for foreign bananas (17.5% upon oven drying at 80°C for 8-11 hrs and 13.92-25.6% upon drying at 70°C for 18 hrs, respectively).

In addition, Madbouly (1979) reported that moisture content differed greatly among the samples tested according to the drying method adopted where it ranged from 16.45 to 17.46%

in oven-dried sliced banana and from 2.99 to 3.19% in freeze-dried powder.

On dry weight basis, no significant change was observed between each of starting fresh bananas and its corresponding untreated dehydrated controls in values for crude protein, ether extract, ash, total carbohydrates and crude fiber. Results obtained are in agreement with those found by Kayisu et al. (1981) who did not find any difference in chemical composition of ripe banana pulp and banana pulp flour prepared by freeze-drying.

On the other hand, no significant variation was found in contents for protein, ether extract, total carbohydrates and crude fiber between untreated dehydrated control and their corresponding treated dehydrated bananas (obtained by using the three treatments), regardless of the kind of banana cultivars. In contrast, with all banana cultivars, there was difference in moisture and ash contents between untreated dehydrated control and their corresponding treated dehydrated bananas. However, all dehydrated samples of the three treatments showed higher values for moisture and ash contents than their corresponding dehydrated untreated controls. Such high contents in moisture and ash could be attributed to the effect of the dipping treatment applied prior to dehydration which envolved the use of some chemical ingredients during the soaking process (e.g., $Na_2S_2O_5$, $CaCl_2$ or ascorbic acid).

In agreement with our data, Kayisu *et al.* (1981) stated that protein, starch, sugars, ash and fibers were not significantly affected by drying of green and ripe bananas.

4.1.2.5. Carbohydrate constituents:

A) Ripe pulps of fresh starting bananas:

Fresh pulp of Maghrabi, Paradica and Sindihi bananas as well as their dehydrated materials were analysed for their content in total sugars, reducing sugars, starch crude fibers as well as pectin fractions, i.e., water-soluble pectin, oxalate-soluble pectin and sodium hydroxide-soluble pectin (Table 10).

Total sugars content of fresh pulp of Maghrabi cultivar was tremendously higher (72.98%) than those of Paradica and Sindihi cultivars (55.17 and 42.94%, respectively). This means that total sugar content of fresh Maghrabi was higher by 32.28 and 69.96% over those found in Paradica and Sindihi cultivars, respectively. Saad (1989) reported lower values for ripe fresh Maghrabi, Paradica and Sindihi bananas and found that they contained 66.43, 43.33 and 35.95% total sugars, respectively.

Data in Table (10) indicated banana pulps of the three cultivars varied in values for reducing and also non-reducing sugars (on dry weight basis). Maghrabi showed the highest content in non-reducing sugars (53.01%), but the lowest content in reducing sugars (19.97%), whilst Paradica cultivar surpassed the other two in content of reducing sugars (53.08%) while had

Table 10: Chemical analysis of some carbohydrate constituents of fresh banana pulp before and after dehydration into dry powder as prepared from three banana cultivars grown in Egypt using different treatments (g/100 g dry weight basis).

Analysis[1]	Maghrabi					Banana cultivar Paradica					Sindihi				
	Fresh pulp	Control[2]	Treat-ment I[3]	Treat-ment II[4]	Treat-ment III[5]	Fresh pulp	Control[2]	Treat-ment I[3]	Treat-ment II[4]	Treat-ment III[5]	Fresh pulp	Control[2]	Treat-ment I[3]	Treat-ment II[4]	Treat-ment III[5]
Total soluble sugars	72.98	72.95	72.90	72.89	72.91	55.17	55.12	55.03	55.03	55.05	42.94	42.87	42.78	42.77	42.79
Reducing sugars	19.97	19.99	19.94	19.93	19.93	53.08	53.11	53.04	53.05	53.05	39.20	39.21	39.16	39.17	39.16
Non-reducing sugars	53.01	52.96	52.96	52.96	52.98	2.09	2.01	1.99	1.98	2.00	3.74	3.66	3.62	3.60	3.63
Starch	5.92	5.88	5.89	5.90	5.90	19.32	19.22	19.25	19.28	19.20	35.42	35.36	35.38	35.39	35.40
Crude fibers	1.56	1.58	1.55	1.55	1.56	1.50	1.52	1.48	1.49	1.49	1.16	1.17	1.15	1.15	1.16
Water soluble pectin	1.65	1.60	1.58	1.57	1.58	1.76	1.74	1.60	1.62	1.70	1.44	1.42	1.40	1.40	1.40
Ammonium oxalate-soluble pectin	0.71	0.72	0.75	0.76	0.74	0.68	0.70	0.81	0.82	0.70	0.78	0.79	0.80	0.81	0.79
Sodium hydroxide-soluble pectin	0.84	0.88	0.85	0.86	0.86	0.61	0.62	0.63	0.61	0.63	0.71	0.73	0.72	0.72	0.73
Total pectic substances	3.20	3.20	3.18	3.19	3.18	3.05	3.06	3.04	3.05	3.03	2.93	2.94	2.92	2.93	2.92

1. Average of duplicate analysis,
2. Dehydrated sliced pulp (without any treatment).
3. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 0.3% $CaCl_2$ for 3 min before dehydration,
4. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 0.4% $CaCl_2$ for 3 min before dehydration.
5. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 1% ascorbic acid for 3 min before dehydration.

the lowest non-reducing sugars(2.09%). Sindihi cultivar had in between values in both reducing (39.20%) and non-reducing sugars (3.74%).

Related reports declared that reducing sugars of ripe banana pulp showed a wide range of variation differences between the different cultivars (Salem _et al_., 1976; Chacon _et al_., 1987; Barthakur and Arnold, 1990).

Data illustrated in Table (10) pointed that starch, content (on dry weight basis) of ripe pulp of Sindihi cultivar was tremendously higher than those Maghrabi and Paradica cultivars (35.42% vs. 5.92 and 19.32%, respectively). So, it follows that starch content of Sindihi is higher by 498.31% and 83.33% than those present in Maghrabi and Paradica cultivars, respectively.

Results obtained are in general agreement with those found by Kayisu _et al_. (1981) for African banana cultivars as well as by Madbouly (1979) and Saad (1989a) for Egyptian banana cultivars. The related literature declared that ripe pulp of (starchy cultivars) contained 3 to 12% starch (Marriott _et al_., 1983). Meanwhile, starch content of ripe pulp of sweet bananas was reported to vary between 0.82 and 2.9% (Von Loesecke, 1950, Simmonds, 1966, Ketiku, 1976, Salem _et al_., 1976, Chacon _et al_., 1987; Abdel-Naby, 1988).

In contrast to starch content, fresh ripe banana pulps of Maghrabi and Paradica exhibited higher comparable content in crude fibers(1.56 and 1.50%, respectively) than that of Sindihi which showed the lowest content (1.16%). However ripe pulps of Maghrabi, Paradica and Sindihi fresh bananas had higher values for crude fiber than those reported by Ketiku (1973) and Izonfuo and Omuaru (1988) for starchy bananas or plantain grown in Nigeria and much lower values than those reported by Kayisu et al. (1981) for bananas grown in Zaire.

Although pectic substances usually constitute a minor percentage of the fruit composition, yet it seems to be responsible for fruit firmness being located in the middle lamella of cell wall.

Pectic substances were determined in fresh and dehydrated bananas as water-soluble fraction (pectin), ammonium oxalate-soluble fraction (pectate or pectinate) and sodium hydroxide-soluble pectin (protopectin) as well as the total pectic substances.

Fresh ripe banana pulp of Maghrabi exhibited the higher content of total pectic substances by 4.99 and 9.22% over those present in Paradica and Sindihi, respectively (3.2 vs. 3.05 and 2.93 mg % on dry weight basis).

With regard to the various pectin fraction fresh Paradica pulp showed the highest amount in water-soluble pectin fraction compared to fresh Maghrabi and Sindihi (57.70 vs. 51.56 and 49.15% of the total pectic substances, respectively). Sindihi had the highest ammonium oxalate-soluble pectin content while Maghrabi and Paradica exhibited comparable values (26.62

vs. 22.19 and 22.3% of total pectins, respectively) although both Maghrabi and Paradica differed in their total pectic substances.

Maghrabi has the highest proportion of NaOH-soluble pectin fraction compared to Paradica and Sindihi bananas (26.25 vs. 20.0 and 24.23% of total pectic substances, respectively).

Comparing the obtained values for total pectins with those in literature revealed that Sharaf et al. (1979) reported lower values for pulp in "Hindi" banana cultivar grown in Egypt, while, in contrast, Valverde et al. (1982) reported higher values for plantains grown in Spain.

B) Dehydrated banana products:

Data of the present study revealed that the predrying treatments as well as the drying conditions (temperature and time) applied during preparation of different dehydrated banana slices, did not influence greatly the carbohydrate constituents originally present in starting fresh bananas. On dry weight basis, there was no significant difference in total, reducing and non-reducing sugars, starch, crude fiber and pectic substances contents between fresh ripe starting bananas and their corresponding dehydrated untreated controls regardless of the kind of banana cultivars. Only the distribution of fraction constituents was influenced by dehydration. Meanwhile, no considerable change was also observed in all carbohydrate constituents of dehydrated untreated controls and their corresponding dehydrated bananas of the three treatments, regardless of kind of banana cultivar.

Although no changes were observed in total pectic substances, on dry weight basis, before and after dehydration of three banana cultivars under investigation results obtained indicated the presence of some changes in their constituent fractions. Water-soluble pectin fraction decreased slightly while oxalate-soluble and NaOH-soluble pectin fractions increased slightly after dehydration with all treatments of three banana cultivars.

In contrast, to our results, Madbouly (1979) found that starch content in air-dried banana slices slightly decreased during the dehydration process whereas in case of freeze-dried banana powder the starch content remained almost constant. Furthermore, Maia et al. (1982) stated that total and non-reducing sugars decreased, while reducing sugars decreased in one cultivar and increased in another one after drying of two Brazilian banana cultivars, which was not observed in the present study.

4.1.2.6. Total soluble and insoluble solids:

A) Ripe pulps of fresh bananas:

Fresh pulps of Paradica and Sindihi cultivars exhibited comparable content in total solids (32.61 and 33.34%, respectively) while Maghrabi had lower content (26.58%) in total solids (Table 11).

Total soluble solids (TSS) reached 22.5, 26.5 and 23.0% in ripe pulps of Maghrabi, Paradica and Sindihi, respectively.

Table 11: Some chemical properties of fresh banana pulp before and after dehydration into dry powder upon preparation from three banana cultivars grown in Egypt using different treatments (on dry weight basis).

Properties	Banana cultivar														
	Maghrabi					Paradica					Sindihi				
	Fresh pulp	Control[1]	Treat-ment I[2]	Treat-ment II[3]	Treat-ment III[4]	Fresh pulp	Control[1]	Treat-ment I[2]	Treat-ment II[3]	Treat-ment III[4]	Fresh pulp	Control[1]	Treat-ment I[2]	Treat-ment II[3]	Treat-ment III[4]
Total solids (T.S)%	26.58	94.37	93.58	93.65	93.01	32.61	94.75	93.45	93.65	93.38	33.34	95.74	94.82	95.14	94.35
Total soluble solids (T.S.S.)%	22.50	-	-	-	-	26.50	-	-	-	-	23.00	-	-	-	-
Alcohol insoluble solids (A.I.S.) %	22.35	22.16	22.18	22.21	22.24	40.54	40.32	40.45	40.50	40.52	55.00	54.55	54.60	54.65	54.78
Total acidity (as malic acid) %	1.43	1.44	1.50	1.50	1.75	1.93	1.93	1.98	1.99	2.10	1.89	1.89	1.92	1.93	2.11
pH value	5.77	5.76	5.69	5.70	5.68	4.72	4.72	4.65	4.65	4.61	4.70	4.70	4.62	4.61	4.60
Ascorbic acid mg/100 g	31.42	19.50	19.66	19.67	235.42	12.65	7.85	7.92	7.91	166.86	15.96	9.86	10.01	10.03	206.21
Carotenoids mg/100 g	1.44	1.25	1.34	1.33	1.36	1.09	0.92	0.98	0.97	1.02	1.06	0.91	0.95	0.94	0.98
Total phenols mg /100 g	206.44	160.29	162.93	164.44	175.92	175.42	140.49	143.01	144.90	150.58	146.16	130.40	134.81	135.06	137.84
Colour index[5]	0.020	0.034	0.024	0.021	0.026	0.017	0.024	0.019	0.018	0.020	0.018	0.029	0.023	0.020	0.025
Serum colour[6]	64.00	60.10	62.40	63.20	60.70	65.00	60.80	63.00	64.80	61.20	88.40	77.20	81.40	82.80	78.40
Residual sulphur dioxide ppm.	-	-	228.0	220.0	216.0	-	-	246.0	239.0	235.0	-	-	265.0	260.0	257.0
Dry ratio	-	3.55:1	3.52:1	3.52:1	3.50:1	-	2.91:1	2.87:1	2.87:1	2.86:1	-	2.87:1	2.84:1	2.85:1	2.87:1

1. Dehydrated sliced pulp (without any treatment).
2. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 0.3% $CaCl_2$ for 3 min before dehydration.
3. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 0.4% $CaCl_2$ for 3 min before dehydration.
4. Sliced pulp dipped in 1% $Na_2S_2O_5$ + 1% ascorbic acid for 3 min before dehydration.
5. Measured as optical density at 420 nm.
6. Measured as transmission at 420 nm.

However, upon comparing the proportion of TSS to total solids of three cultivars, ripe fresh Maghrabi pulp had higher value (84.65%) than those for Paradica and Sindihi (81.28% and 68.98%, respectively).

Ripe fresh pulps of Maghrabi, Paradica and Sindihi bananas varied remarkably in their contents of alcohol-insoluble solids (22.35, 40.54 and 55.0%, respectively) where Sindihi had the highest value compared to Paradica and Maghrabi bananas probably due to its higher starch content (34.42%, Table 10).

In agreement with our results, Maia et al. (1982) indicated consistent values for soluble solids (26.2% and 19.4%) for two Brazilian banana cultivars. Madbouly (1979) reported also an average TSS value for 22.0% for ripened Hindi Egyptian cultivars. Moreover, Chacon et al. (1987) mentioned also that TSS of ripe Latin American bananas reached 22.6%.

B) Dehydrated banana products:

An increase in total solids and a very slight decrease in alcohol-insoluble solids occurred as a result of dehydration with all treatments of three bananas. Compared to the initial level in starting fresh bananas, the rate of increase in total solids as a result of dehydration for all treatments ranged between 249.9 to 255.0%, 186.4 to 190.6% and between 183 to 187.2% for Maghrabi, Paradica and Sindihi bananas, respectively.