SEED OIL AND MEAL PROTEIN DEVELOPMENT WITH MATURITY OF THE JOJOBA SEED.

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RESUMO

DESENVOLVIMENTO DO ÓLEO DA SEMENTE DE JOJOBA E DAS PROTEÍNAS DE SEU RESÍDUO RELACIONADOS COM SUA MATURAÇÃO.

Simmondsia chinensis (Link) Schneider — jojoba — um arbusto dióico do deserto, nativo do sudoeste dos Estados Unidos e noroeste do México, foi estudado durante um ano de investigação em três diferentes áreas no Arizona, U.S.A., levando-se em consideração o desenvolvimento do óleo de sua semente e da proteína do resíduo da semente após a extração deste óleo, relacionando-o com a sua maturidade.

As áreas 1 e 2 estão localizadas nas faces Este e Oeste, respectivamente, das montanhas de Tucson, e a área 3 está localizada ao sul das montanhas de Santa Catalina. A capacidade de disponibilidade d'água no solo, o potencial de evapotranspiração e a precipitação anuais foram determinadas para cada área estudada.

O método usado para a extração do óleo da semente foi descrito por SALEEB et alii[9]. A proteína foi determinada pelas técnicas de Kjeldahl e BIO-RAD[1].

Frutos no início de maturação apresentaram os maiores teores em umidade e sementes com os mais baixos pesos secos. Frutos no estágio de completo amarelecimento foram os que apresentaram maior peso seco.

O peso médio da semente no estágio de completa maturação foi de 0,54 g na área 1, 0,46 g na área 2 e 0,68 g na área 3. Esta área foi a que apresentou sementes mais espessas e frutos com menos casca e mais sementes.

O conteúdo de cera líquida aumentou com a maturidade da semente. Este conteúdo tendeu se relacionar com o tamanho do fruto mas não guardou nenhuma relação com o peso de sua semente.

Usando-se um método colorimétrico, o teor de proteína da semente foi mais alto no estágio inicial de maturação do fruto. Quando se usou um método baseado no nitrogênio total, este teor foi mais alto no estágio de completa maturação da semente.

PALAVRAS-CHAVE: Jojoba, Semente, Óleo, Proteína, Resíduo, Maturação, Desenvolvimento.

SUMMARY

Simmondsia chinensis (Link) Schneider — Jojoba — a dioecious desert shrub, native to Southwestern United States and Northwestern México, was studied during an intensive one year investigation at three diferent sites in Arizona considering the development of the seed oil and meal protein in relation to the maturity of the seed.

Site 1 is located on the eastern slope of the Tucson Mountains; site 2 is on the west side of the Tucson Mountains, and site 3 in the southern foothills of the Santa Catalina Mountains. The available water capacity, the annual potential evapotranspiration and precipitation were determined for each site of study.

The method of extraction of the seed oil was that described by SALEEB et alii[9]. Protein was determined by the Microkjeldahl and the BIO-RAD[1] technique using conventional methods for extracting proteins.

Fruits at the beginning of maturation had the highest moisture content and the lowest dry seed weight. Dry fruits reached their highest weight at the full yellowing stage.

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Seed weight at full maturation averaged 0.54 g at site 1, 0.46 g at site 2, and 0.68 g at site 3. In addition to larger seeds, site 3 had fruits with less hull and more seed.

Wax content increased with maturity of the seed. Wax content tended to relate to fruit size but not to seed weight.

Using a dye method, protein content of the seed reached its highest value at the beginning of maturation. Using a method based on the total nitrogen determined, protein content was highest at full maturation of the seed.

KEY-WORDS: Jojoba, Seed, Oil, Protein, Maturation, Development.

INTRODUCTION

Jojoba, according to SHERBROOK & HAASE[11], is the only higher plant known to produce liquid wax. One of the most positive features of jojoba seed oil is that it can substitute for sperm whale oil, possibly avoiding the future extraction of this animal species. DE LA VEGA[4] reported that jojoba seed oil has qualities superior to sperm whale oil. Moreover the NATIONAL ACADEMY OF SCIENCES[7] stated that, chemically, jojoba oil has industrial advantages over sperm oil. DE LA VEGA[4] reported that the seed residues, after the extraction of the oil, contain 30 percent protein, a point that justifies its use as livestock feed. However, BOOTH[2] reported that seed meal fed to rats was toxic to some individual animals.

He says that it is not clearly established the extent to which animals will ingest the oil-bearing seeds, and if so whether any adverse effects are produced. COTGAGEORGE et alii[3] found a very successful method to detoxify the meal as confirmed by mouse feeding tests. Both protein quality and quantity were generally unaffected by the treatments.

GENTRY[6], working with plants from Arizona, Baja California and California, found seed liquid wax percentage ranging from 37.8% to 54%, with averages 45.6% in 1957 and 51% in 1954.

YERMANOS[15], working with jojoba seeds from Aguanga, California, found a mean of 51.8% of liquid wax when determinations were made by petroleum ether extraction technique and 53.1% when working with the wide line Nuclear Magnetic Resonance Spectroscopy. YERMANOS & DUNCAN[17] reported that the wax and protein content of seeds picked from plants from the same area were not very different in the years of 1973 and 1974.

FELDMAN[5] found significant differences between 1973 and 1974 wax percentage. Most seeds were picked in Arizona and some in California. In 1974, the wax percentages ranged form 44.53% to 55.03% with a mean of 48.76%. The wax percentages among 15 individual plants ranged from 42.07% to 54.32%, with a mean of 48.76%. The wax percentages of 19 individual plants at the Tonto Experimental site in 1973 ranged from 39.33% to 51.5% with a mean of 46.74% and in 1974, the wax percentages, from same plants, varied from 41.3% to 53.9% with a mean of 49.8%.

The NATIONAL ACADEMY OF SCIENCES[8] stated that the most jojoba nuts contain 45 to 60 percent oil, and the average is close to 50%.

WELLS[14] stated that in addition to the high oil content of jojoba nuts, its economic use will depend to a great extent on the value of the meal left after extraction of the oil. Seeds harvested in Arizona in 1942 containing 4.1% moisture, 12.5% ash, and 45.2% oil showed the following results in the seed meal:

	Oil seed meal (%)	Whole bean (%)
Protein (N x 6.25)	31.5	16.1
Carbohydrates		
Reducing sugars, as glucose	8.9	4.6
Non-reducing sugars, as sucrose	3.7	1.9
Other carbodyrates, as starch	16.0	8.2
Ash	3.08	1.57

YERMANOS[16] found 32.6 percent protein (N x 6.25) in jojoba nut free oil at full maturity.

The NATIONAL ACADEMY OF SCIENCES[8] reported that the protein content of jojoba nuts, after the oil extraction, varies from 26.3% to 32% with a mean close to 30%.

The literature does not make any assumption about development of wax and protein concentrations in relation to the maturity of the seed.

The main objective of this research was to study the development of the seed oil and meal protein of the desert shrub jojoba in relation to the maturity of the seed.

MATERIAL AND METHODS

During an intensive one year investigation of jojoba, oil and meal protein development with maturiy of its seed were studied at three different sites in Arizona.

Site 1, on the eastern slope of the Tucson Mountains is located on Speedway Blvd. close to the Painted Hills Road, 10 km west of the University of Arizona Campus. The elevation of the site is 790 m and its topography is undulating. The available water capacity was 0.8 inch of water per foot of soil. The annual potential evapotranspiration, according to THORNTHWAITE[12] and THORNTHWAITE & MATHER [13], and the annual precipitation were 1,081.0 mm and 409.7 mm, respectively.

Site 2, on the westside of the Tucson Mountanis, is located at an elevation of 820 m in the Tucson mountain Park, west of Tucson, 24 km from the University of Arizona Campus. Its topography is almost level with 1 to 3 percent slope. The available water capacity was 0,8 inch of water per foot of soil. The annual potential evapotranspiration according to same authors as above, and the annual precipitation were 1,133.0 mm and 418.3 mm, respectively.

Site 3, in the southern foothills of the Santa Catalina Mountains, north of Tucson is located 14 km from the University of Arizona Campus. The elevation of this site is 850 m and its topography is almost level with a slope of 1 to 3 percent. The available water capacity was 1,0 inch of water per foot of soil. The annual potential evapotranspiration according to authors reported above, and the annual precipitation were 1,080 mm and 493.6 mm, respectively. The percentage of wax and the total protein content after wax extraction were determined for the seeds. Seeds were analyzed in four stages of development to determine the evolution of oil and meal protein with maturity of the seed. Only the ten selected plants were used for this purpose. The stages of development considered were: (1) starting of maturation; full yellowing of the fruit; full maturation one, and full maturation two. The full maturation stage one was reached when 25 to 50% of the fruits on each plant were completely mature. The indication of full maturation was the beginning of fruit dehiscence. Only dehiscent fruits were harvested. The full maturation stage two was reached when more than 50% of the fruits on a plant were completely mature. At that time, all fruits were either mature or near maturity. For the first three stages of development, the fruits were weighed immediately after harvesting and brought to the laboratory in an ice chest containing dry ice at a temperature of -40°Celsius. At the laboratory, the samples were dried at -50° Celsius in a freeze dryer made by Labconco Corporation. The full maturation stage two fruits were dried under full sunlight. Tem samples were then chosen, weighed and freeze dried. The size of each plant sample was limited to three fruits. Some fruits were double-seeded. The samples were limited to this size because two plants of site number two produced only twelve fruits each. For each stage, all fruit lenghts and diameters were averaged to determine relationships between fruit size and the concentration of wax and protein. Fruit moisture, fresh and dry weight of fruits, and the weights of seed, hull, and seed meal were also determined. The method of extraction of the seed oil was that described by SALEEB et alii[9]. This method was used with jojoba by YERMANOS[15] and FELDMAN[5]. The solvent used in our work was reagent grade hexane with a boiling range not more than five degree Celsius. Protein was determined by the Microkjeldahl and the BIO-RAD[1] technique using conventional methods for extracting proteins. As the first technique estimates the protein base on the total nitrogen present in the sample, presumably including nonprotein-nitrogen, a method which is based only on protein is desirable.

RESULTS AND DISCUSSIONS

The pattern of growth of the fruit was similar at all sites, the hulls enlarging in the early stages and shrinking later. Three to four weeks after the onset of maturation the fruits declined in size, in both length or diameter, and in fresh weight. According to these data shown in Table 1 these components decreased gradually from the beginning of maturation to complete maturation. Because of the high variation of these data in each site, their means were not statistically different at a 5% level of significance. However, in absolute values, site 3 plants were always higher in these above mentioned variables. Plants in site 3 had larger fruits and seeds because precipitation, soil development, and available water capacity were more favorable for jojoba growth and development. Dry fruit weight was not statistically different within and among locations at a level of 5% significance, however, it was observed that dry fruits reached their highest weight at full yellowing at all sites. Fruit at the beginning of maturation had the highest moisture content and the lowest dry seed weight at all sites of study. YERMANOS[16], working with seeds from a natural stands of jojoba in the vicinity of Aguanga, Ca-

Table 1

Phenological and Physiological Jojoba Fruit and Seed Variables at Four Development Stages at Three Sites in Arizona, U.S.A.

Site	Stage of Development	Fruit Size (mm) Length	Diam.	Fruit wt. (g) Fresh	Dry	(%)	Dry Fruit Separates (g) Seed	Hull	Meal	Seed Hull Ratio	Wax (%)	Protein (%)
	Maturation Starting	23.50	13.5	1.82	0.64	64.3	0.33	0.31	2076	1.1	37.1	25.9
1	Full Yellowing	21.3	12.6	1.65	0.83	49.5	0.57	0.26	3545	2.2	37.8	19.6
	Full Maturation 1[1]	20.8	11.5	0.88	0.79	8.6	0.54	0.25	2905	2.2	46.2	21.2
	Full Maturation 2[1]	20.2	11.4	0.77	0.75	1.7	0.50	0.25	2615	2.0	47.7	18.8
	Maturation Starting	23.3	14.0	2.00	0.69	65.5	0.36	0.33	2372	1.0	34.1	27.6
2	Full Yellowing	21.4	13.7	1.75	0.95	45.3	0.67	0.29	3933	2.4	41.3	22.4
	Full Maturation 1[1]	19.8	11.4	0.76	0.73	4.5	0.46	0.27	2470	1.8	46.3	22.3
	Full Maturation 2[1]	19.0	12.2	0.79	0.78	1.9	0.53	0.25	2984	2.1	43.7	21.3
	Maturation Starting	24.6	15.2	2.46	0.77	68.5	0.41	0.36	2645	1.1	35.5	27.5
	Full Yellowing	22.5	14.4	1.91	1.10	42.1	0.81	0.29	4836	2.8	40.3	20.7
3	Full Maturation 1[1]	21.8	12.6	1.08	0.93	13.7	0.68	0.25	3482	2.8	48.8	21.6
	Full Maturation 2[1]	21.5	13.7	1.16	1.13	1.8	0.85	0.28	4437	3.1	47.8	21.9

[1] See text (Materials and Methods)

lifornia, found similar results. As shown in Table 1, the dry seed weight like the dry fruit weight tended to be higher at full yellowing of the fruit. Seed hull ratio tended to be 1.0 at all sites at the first stage studied. However, while at the two first this ratio was about 2.0 for the other stages, it was approximately 3.0 for the third site of study. Apparently in addition to larger seeds, either in size or weight, site 3 had fruits with less hull and more seed, a desirable characteristic for exploitation of the seed alone. An increase of wax content with maturity of the seed was noted from the first stage of maturation to complete maturation at all study sites (Figure 1). YERMANOS [16] observed an increase of jojoba wax with seed maturity. The comparison among the means among location was not statiscally different at 5% level of significance. When considering the overall mean for the whole site, wax content tended to be related to the size of fruit but not with the weight of the seed. Consequently wax content of the seed showed some relationship to precipitation, and development and available water capacity of the soil.

At all sites, using a dye color method, protein content of the seed reached its highest value at the beginning of maturation. SALISBURY & ROSS[10] (p. 366) reported that protein synthesis occurs fastest in rapidly growing organs, such as young roots, stems, leaves, and flowers and in developing seeds. In this research, according to data in Table 1 and Figure 1, after onset of maturation of the fruit, protein decreases approximately 20%, maintaining a relatively constant content until complete maturity. This was apparently the same at all sites of study. Considering the fruit when green in color and full expanded but not yet mature, it would seem that as soon as jojoba fruit starts to mature the relative rates of photosynthesis in the fruit declines and rates of degradation, particularly, of protein increase. Presumably, part of protein is reduced to amino acids which are probably gradually respired.

It is important to note that all characteristics of fruits, either mature or near maturiy, when harvested and placed under full sunlinght (full maturation 2) showed practically no difference compared with those characteristics of

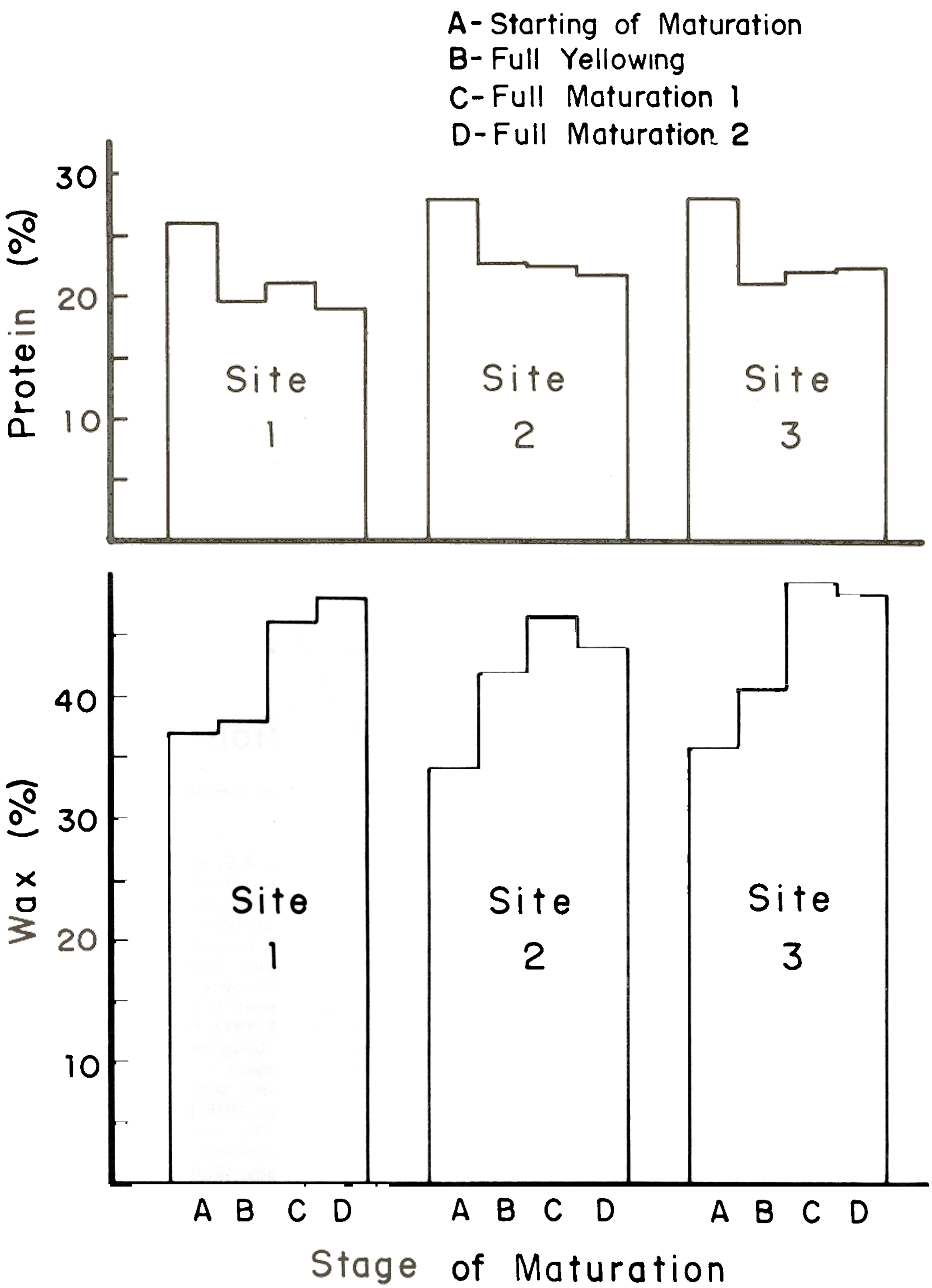

FIGURE 1. Seed wax and meal protein development with maturity of the seed at the three sites of study; protein content as determined by Bio-Rad technique.

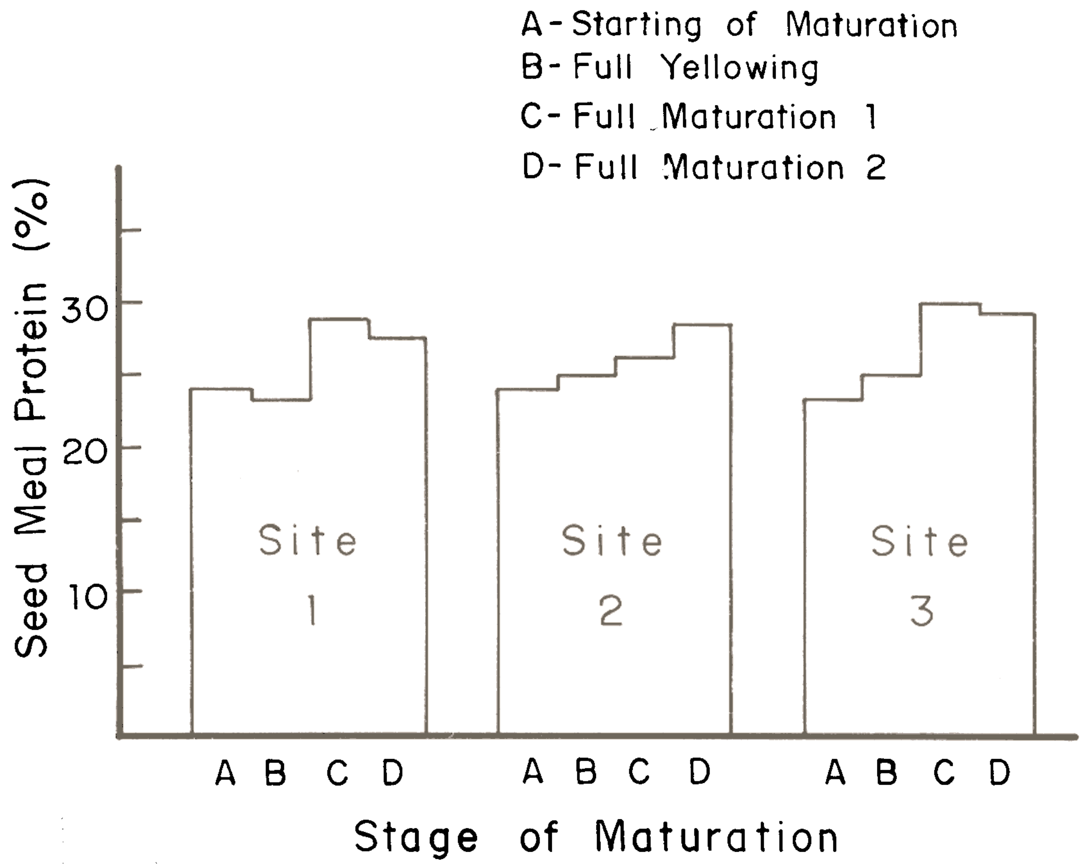

FIGURE 2. Seed meal protein development with maturity ot the seed at the three sites of study; protein content as determined by Microkjeldahl technique.

fruits harvested at complete maturiy (full maturation 1). Additional experimentation is suggested to see if that procedure affects germination of the seed and the quality of its oil.

Protein was also determined using the Microkjeldahl method. The trend of protein development with maturiy of the seed was similar to part of the results reported by YERMANOS[16]. A gradual increase was observed in the protein content, but not reaching the high values reported in his work (Figure 2). These results were almost the opposite (in terms of stages of maturation) found with the color method. It is suggested here that these determinations be restudied.

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