Reprinted from *J. Food Sci.* 51(4): 967–970
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Exhibit 6b, Pub. #62

Preparation, Evaluation and Analysis of a French-Fry-Type Product from Sweet Potatoes

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ABSTRACT

A French-fry-type product was prepared from 'Jewel' and 'Centennial' sweet potatoes. Samples were prepared from freshly harvested, cured, and stored, cured roots. The roots were peeled, sliced into strips and blanched in hot water. The blanched strips were partially dehydrated by one of five treatments and then frozen at −30°C. Frozen strips were fried in hot peanut oil and evaluated by a sensory panel. Strips prepared by dehydration in a hot air tunnel at 120°C for 5 min were favored by the sensory panel. Blanching removed significant amounts of dry matter and resulted in partial hydrolysis of the starch by endogenous enzymes. Sensory color scores were not affected by reducing sugar content. Sensory flavor scores were related to total sugar content.

INTRODUCTION

PROCESSED SWEET POTATO PRODUCTS of limited variety are available to most consumers. At present the canned product, frozen patties and frozen pieces constitute the major consumer-available forms. Of these, only canned sweet potatoes are widely distributed and consumed. The deep orange colored root preferred in the United States (Law, 1977) contains significant amounts of pro-vitamin A and vitamin C and thus could serve as an additional source of these vitamins if available in other acceptable forms.

One product which would seem to hold promise is a frozen French-fry. The rate of consumption of French-fried white potatoes has increased rapidly in the last decade and in 1978 stood at about 18.1 kg per person per year (USDA, 1980). If a similar product prepared from sweet potatoes were available, it might be acceptable to a large number of consumers.

Preparation of a high quality, fried chip product has been reported by several groups (Kelley et al., 1958; Hoover and Miller, 1973; Olorunda and Kitson, 1977; Hannigan, 1979). One of the major problems reported by these workers was discoloration which arises from two different sources. The first of these is formation of a gray discoloration thought to be caused by the reaction between o-dihydroxyphenols and iron III (Hoover, 1963). The second type of discoloration is nonenzymatic browning, which results when reducing sugars condense with amino groups (Spark, 1969). The rate of this reaction is increased at the high temperatures attained in oil frying.

Several methods have been reported which control discoloration in sweet potato products. Hoover and Miller (1973) used a sodium acid pyrophosphate blanch treatment to eliminate graying. Olorunda and Kitson (1977) eliminated discoloration in chips prepared from white fleshed varieties by a sodium sulfite (SO_2) dip. This type of treatment served to block enzyme-caused phenolic discoloration and to remove some of the reducing sugars. At harvest, sweet potatoes contain ≤0.1% reducing sugar (glucose and fructose). The reducing sugar content increases during storage of cured roots and can reach >2% after several months (Walter and Hoover, 1984). Hannigan (1979) reported removal of 90–100% of the sugar from raw slices with a slope diffuser which combined water extraction and blanching steps. The de-sugared, blanched chips were oil fried, and a light colored, flavorful product resulted. Olorunda and Kitson (1977) demonstrated that the sugar content can be lowered by storing the roots at 30°C for several weeks before processing. Thus, discoloration can be reduced if the o-dihydroxyphenol-Fe III and sugar-amino reactions are minimized.

Flavor and texture are the other quality factors which are affected by both post-harvest handling and pre-frying processing conditions. In general, cured and stored sweet potatoes, when baked, are more flavorful than freshly harvested roots (Hammett and Barrentine, 1961). The increase in desirable flavor is due to both an increase in sugars and other undefined flavor components (Hamann et al., 1980). Since some of the sugar must be removed to prevent browning, it is likely that when a blanching or water extraction step is used some of the flavor components will also be extracted. Textural properties are dependent on the way in which structural components of a food are arranged (deMan, 1976). Thus, texture is not nearly as strongly affected by water extraction as is the sugar content. Post-harvest history of the roots is strongly related to textural properties. Rao et al. (1975) showed that the viscosity of baked sweet potatoes decreased with length of storage of the roots prior to baking.

Kelley et al. (1958) also prepared a French-fried sweet potato product. They used no pre-frying treatment and reported that a good quality product was obtained by oil frying the sliced potatoes, cooling, and then freezing the fried slices. The frozen, fried slices were oven cooked prior to being eaten. These workers reported good color, flavor and texture for sweet potatoes cured and stored for about 1 month. When roots stored for 6 months were processed, an inferior texture and taste resulted.

Table 1—Dehydration treatments of the sweet potato french fries following the hot water blanch and prior to freezing

Number	Treatment
1	Control—Cooled 5 min with forced air at 25°C
2	Dehydrated 2.5 min with forced air at 121°C
3	Dehydrated 5.7 min with forced air at 121°C
4	Dehydrated 10.7 min with forced air at 121°C
5	Dehydrated 16.4 min with forced air at 121°C

Table 2—Dry matter and oil content[a,b] of blanched, dehydrated 'Jewel' sweet potato strips and oil-fried strips

Drying		Dry matter	
treatment[c]	Oil	Fried[d]	Unfried
2	19.63	58.49	26.27
3	15.59	58.42	29.57
4	16.12	60.48	36.94
MSD[e]	2.59	3.21	4.02

[a] Percent by weight.
[b] Means of data from uncured, cured, 8-wk, 16-wk, and 24-wk samples.
[c] See Table 1.
[d] Includes dry matter present in unfried strips and oil absorbed during frying.
[e] Minimum significant difference (P≤0.05).

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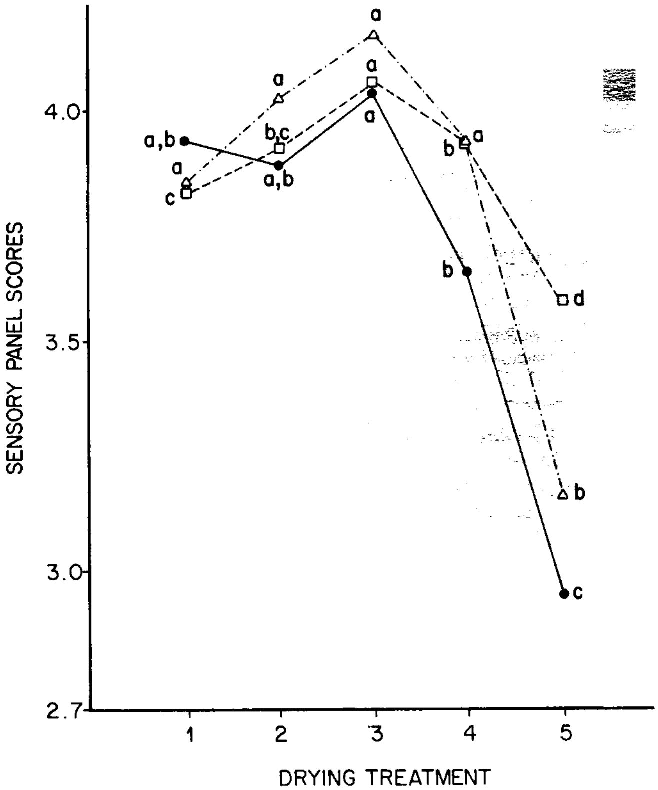

Fig. 1—Effect of drying treatment on sensory panel scores for texture △-·-·-·-△, color ●———●, and flavor □---□. Data are pooled means from fried 'Jewel' and 'Centennial' sweet potatoes. Sensory characteristics with the same letter for differing drying treatments are not different at the P≤0.05 level.

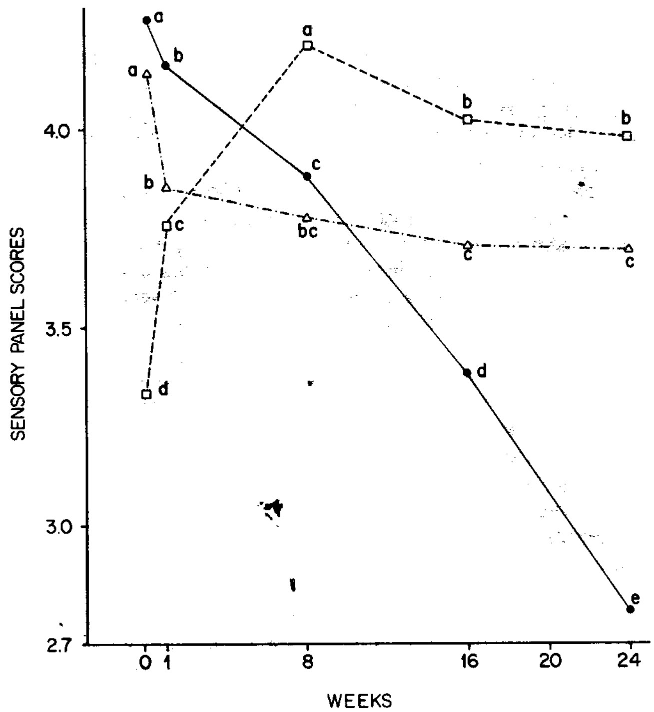

Fig. 2—Effect of post-harvest treatment on sensory panel scores for texture △-·-·-·-△, color ●———●, and flavor □----□. Data are pooled means from fried 'Jewel' and 'Centennial' sweet potatoes. Sensory characteristics with the same letter for differing storage times are not different at the P≤0.05 level.

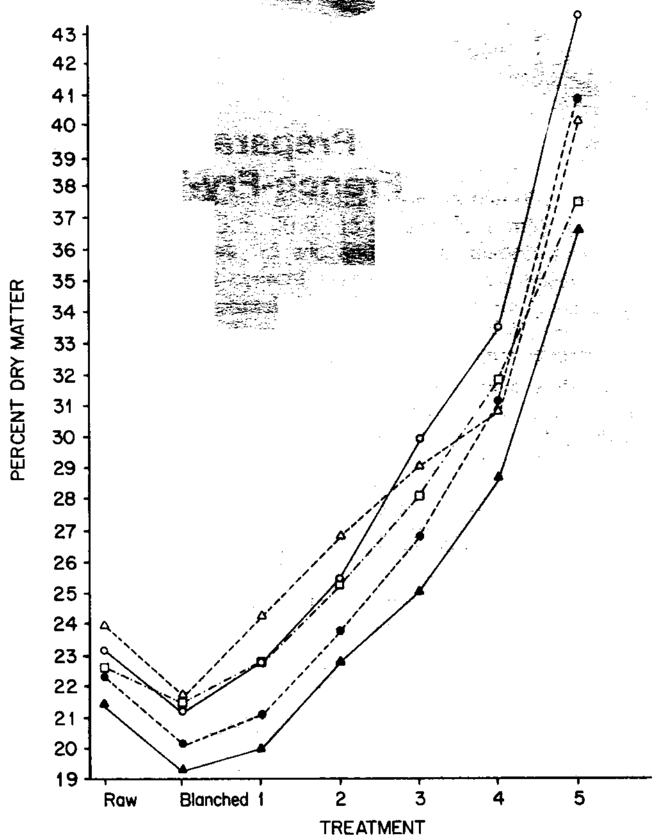

Fig. 3—Effect of drying treatment on percent dry matter for 'Jewel' sweet potatoes. Uncured ○———○, cured △----△, cured and stored 8 wk □-·-·-□, 16 wk ●----●, and 24 wk ▲———▲. Minimum significant difference (P≤0.05) is 2.69% dry matter.

The purpose of this study was to prepare a French-fry-type product from two sweet potato cultivars and to evaluate the effect of varying processing conditions and length of storage before processing on sensory properties and selected chemical components.

MATERIALS & METHODS

'JEWEL' AND 'CENTENNIAL' cultivars were obtained at harvest from a producer in Johnston County, NC. One lot of each cultivar was processed immediately. The remainder of the roots was cured 7 days under recommended conditions (Wilson et al., 1980). After curing, one lot from each cultivar was processed into strips, and the rest held under recommended storage conditions (Wilson et al., 1980) until processed. Roots were processed after 8, 16 and 24 wk.

Processing conditions

The roots were washed, lye peeled and sliced into strips 1.9 × 6.4 cm thick. The strips were blanched in water at 100°C containing 1% sodium acid pyrophosphate for 2.5 min, and except for the control lot, the blanched strips were partially dried in a continuous upward flow, forced air drier at 121°C. Drying time for each batch was regulated by the belt speed (Table 1). The dehydrated strips were frozen and held in high density polyethylene freezer bags at −34°C until fried.

Sensory evaluation

Evaluations were conducted after all of the cured, stored samples had been processed. For panel evaluation, the frozen strips were fried at 175°C for 2.5 min. The fries were presented to an 18 member, untrained sensory panel consisting of staff and graduate students from the Dept. of Food Science at North Carolina State Univ. Panelists were served coded samples on white plates in fluorescent lighted rooms and were asked to evaluate color, flavor and texture on a 5-point scale (5 = excellent, 4 = good, 3 = fair, 2 = poor, 1 = unacceptable).

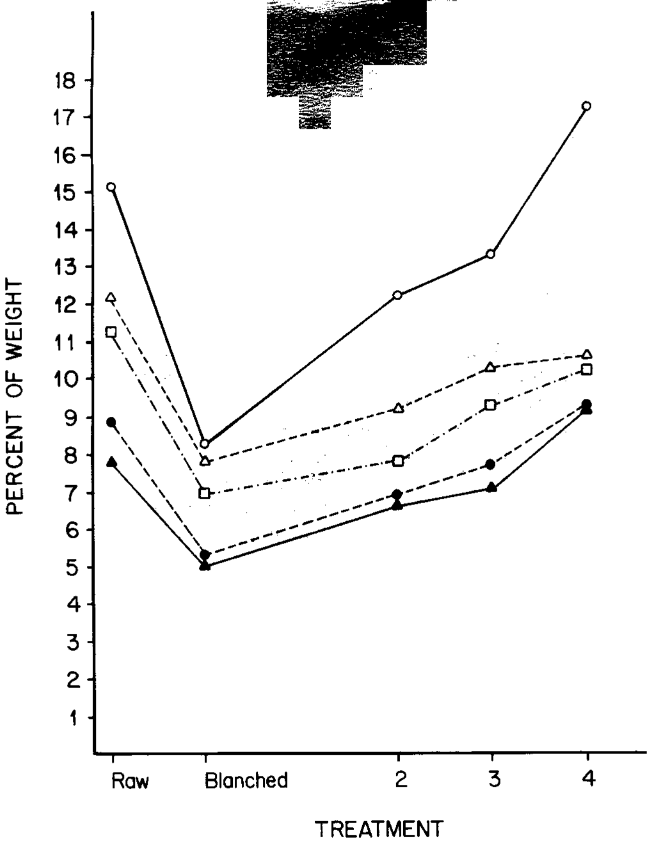

Fig. 4—Effect of drying treatment on percent starch for 'Jewel' sweet potatoes. Uncured ○———○, cured △----△, cured and stored 8 wk □-·-·-□, 16 wk ●----●, and 24 wk ▲———▲. Minimum significant difference (P≤0.05) is 0.28% of weight.

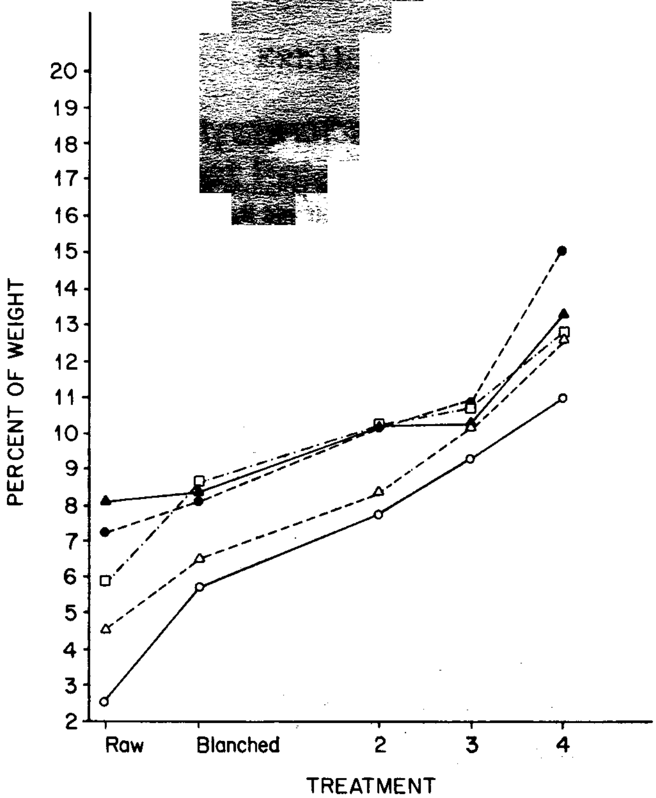

Fig. 5—Effect of drying treatment on total sugar content for 'Jewel' sweet potatoes. Uncured ○———○, cured △---△, cured and stored 8 wk □-·-·-□, 16 wk ●----●, and 24 wk ▲———▲. Minimum significant difference (P≤0.05) is 0.40% of weight.

At each sitting the treatments for one cultivar were evaluated (five samples). The data were analyzed by the analysis of variance (ANOVA) and general linear model (GLM) procedures of the Statistical Analysis System (SAS, 1982a, b).

Chemical analyses

The analyses described below were performed on 'Jewel' cultivar. Dry matter was determined by weighing duplicate samples before and after drying in a force draft oven at 60°C for 18 hr, followed by a temperature treatment at 100°C until constant weight was attained. Alcohol-insoluble solids, sugars, and starch were measured as described by Walter and Hoover (1984). Oil content of fried strips was measured on dried powdered fried samples by Soxhlet extraction with hexane for 24 hr, followed by evaporation of the hexane and weighing the residue. Since the fat content of sweet potatoes is less than 1% by weight (dry basis), endogenous fat was neglected.

RESULTS & DISCUSSION

Sensory evaluation

Since both cultivars showed similar trends for sensory scores, the data are presented as means. Flavor scores increased as the time in the drying tunnel increased and peaked at treatment (TMT) 3 (Fig. 1). Mean scores for texture and color also showed a trend toward a maximum at TMT 3. However, texture scores for TMT 1-TMT 4 were not statistically different (P≤0.05) and color scores for TMT 1-TMT 3 were not statistically different (P≤0.05). Color and texture scores declined more than flavor scores as the severity of the drying treatment increased.

Post-harvest handling of sweet potatoes exerted a significant influence on the finished product. When the data for all five dehydration treatments were pooled, it was seen that flavor scores increased from harvest until 8 wk of storage and then tended downward (Fig. 2). Similar improvement in sensory

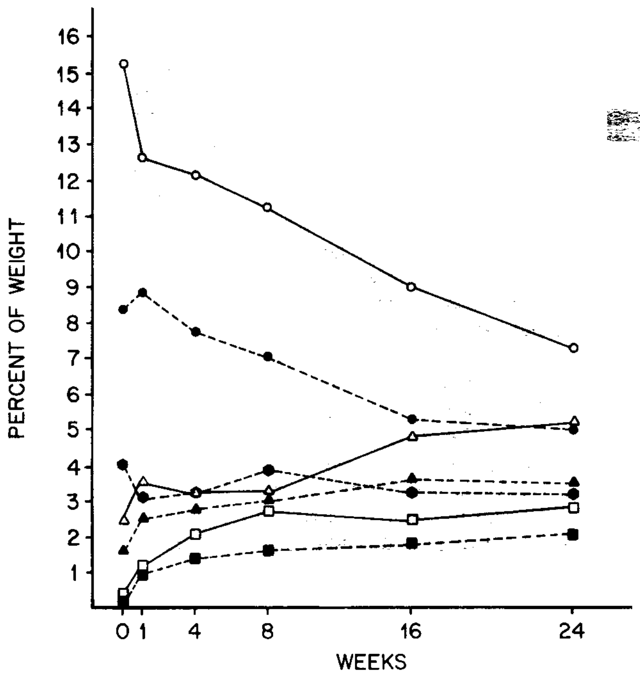

Fig. 6—Effect of post-harvest treatment on the content of starch (○), maltose (○), sucrose (△), and glucose plus fructose (□) for raw and blanched 'Jewel' sweet potatoes. Solid lines and open symbols represent raw samples. Broken lines and darkened symbols represent blanched samples. Maltose was not found in raw samples. Minimum significant differences (P≤0.05) as percent of weight are starch, 0.51; maltose, 0.48; sucrose, 0.25; and glucose plus fructose, 0.08.

quality for cured, stored sweet potatoes has been reported for baked sweet potatoes (Hammett and Barrentine, 1961) and for cooked, dehydrated flakes (Hoover and Kushman, 1966). Color scores decreased in a regular fashion throughout the storage period. Sistrunk (1977) also reported a decrease in both sensory color scores and color difference meter readings for stored sweet potatoes. On the other hand, texture scores declined rapidly during curing and then decreased slowly for the remainder of the storage period (Fig. 2). Thus, processing cured or stored cured roots would eliminate considerable variables in both texture and flavor and would seem to give a more consistent product scoring in the upper "fair" to low "good" range. Color scores, however, declined to below "fair" after 24 wk. Thus, sensory data indicated that a slight advantage accrued from drying to TMT 3 and that the most consistent product was produced from cured roots stored no more than 24 wk after harvest.

Compositional analysis

The percent dry matter (DM) of raw roots ranged from 23.8 to 21.4%, tending to decrease with increasing length of storage (Fig. 3). Dry weight decreased during storage because the roots were metabolically active and utilized carbohydrates as an energy source and because of transpiration during storage. Blanching the roots caused a further decrease in DM because part of the sugars and other water-soluble materials were extracted by the hot water. The drying treatments resulted in a progressive increase in DM. Starch and sugars make up a large portion of the dry matter and are concentrated as the moisture level is decreased by the drying treatments (Fig. 4 and 5).

Beginning with TMT 3, the DM at each harvest date was greater than the DM of the corresponding raw roots. Dry matter tended to increase with each drying treatment (Fig. 3). The mean DM of strips summed over all treatments declined from 31% at harvest to 30.2% after curing (1 week), while the texture scores declined from 4.14 to 3.85 (Fig. 2). Such a slight change in DM is not likely to have caused the decline in texture scores, particularly in view of the fact that texture scores declined gradually to 3.65 for the remainder of the study while DM declined to 26.6% after 24 wk.

Starch content declined and sucrose, glucose and fructose levels increased during storage (Fig. 6). Blanching caused a further decrease in starch content. Microscopic examination of the blanched strips showed that starch gelatinization and some cellular disruption occurred, indicating that heat penetration from the blanch water raised the internal temperature above the starch gelatinization temperature of 59–72°C (Madamba et al., 1975). Native amylases then hydrolyzed part of the starch. As a result, maltose, although not detectable in the raw strips, was found to be >2.5% by weight. Blanched samples contained less sucrose, fructose and glucose than did raw samples because of aqueous extraction. Sugar content of the blanched samples increased from 6.5% after curing to 8.9% in roots stored 24 wk. Thus, using pooled treatment means changes in flavor score seemed to be related to sugar content. The simple correlation coefficient between sugar content (Fig. 6) and the mean treatment flavor scores (Fig. 2) was 0.81 ($P \leq 0.05$).

However, as shown in Fig. 5 for drying treatment differences, the sugar content and, thus, the sweetness increased with increased moisture removal. Flavor scores declined after TMT 3 (Fig. 1). Perhaps off-flavors developed which offset the increase in sweetness.

Since color scores declined with increase in storage time (Fig. 2), the reducing sugar levels were calculated to see if any relationship existed. Reducing sugar content of the blanched strips was 12.3, 13.5, 20.0, 15.0, and 20.1 mM in 100g at harvest, 1 wk, 8 wk, 15 wk, and 26 wk, respectively. Thus, the reducing sugar content peaked after 8 wk storage, while the color score declined on a fairly regular basis throughout the storage period. These data showed that if the sugar-amine reaction was responsible for the decline in color scores, it was not dependent on the reducing sugar content higher than 20 mM/100g.

Frying the blanched, dehydrated strips removed additional water and caused absorption of oil (Table 2). The mean dry matter content of TMTs 2-4 was similar, reflecting both water removal and oil absorption (Table 2). However, the amount of oil absorbed increased with increasing moisture content of the unfried strips.

The data showed that a good quality product could be prepared from either 'Jewel' or 'Centennial' cultivar. The most consistent product was prepared from cured roots stored up to 24 wk after harvest. Flavor and texture scores were 3.75 or better on a scale in which 3 was described as "fair" and 4 as "good." Color scores, on the other hand, declined precipitously between 16 and 26 wk.

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Ms received 1/6/86; revised 3/29/86; accepted 3/29/86.

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