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# AVAILABLE AND UNAVAILABLE CARBOHYDRATE CONTENT OF BLACK GRAM (*VIGNA MUNGO*) AND CHICK-PEA (*CICER ARIETINUM*) AS AFFECTED BY SOAKING AND COOKING PROCESSES

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The effects of soaking (Tap water, sodium bicarbonate solution) and cooking in tap water were investigated on available and unavailable carbohydrate contents and starch digestibility of black grams and chick-peas. Available carbohydrates including total soluble sugars, reducing sugars, non-reducing sugars and starch contents of these two legumes decreased to various extents as a result of soaking and cooking. From 3.43 - 25.63% total soluble sugars and 4.26 - 22.70% starch contents were lost on soaking black grams and chick-peas in tap water and sodium bicarbonate solution. Maximum amounts of total soluble sugars (28.43 - 59.64%) and starch contents (29.93 - 67.40%) were lost on cooking the water and alkali soaked legumes. However, these losses were comparatively less in case of water soaking process. Soaking and cooking processes also brought about some changes in the profile of unavailable carbohydrates of black grams and chick-peas. Soaking in sodium bicarbonate solution led to an appreciable increase of hemicellulose (42.50 - 54.31%) and NDF (28.69 - 30.68%) but not in legumes soaked in tap water. However, cooking process caused reduction in NDF (19.25 - 41.04%), ADF (5.48 - 25.31%), cellulose (12.88 - 28.42%) and hemicellulose (31.86 - 59.37%). Lignin contents of these legumes increased to some extents on cooking whereas it remained unchanged as a result of soaking . Starch digestibility of black grams and chick peas was markedly improved after cooking. However, no appreciable improvement in starch digestibility was observed after soaking these legumes in tap water or alkaline solution.

***Key words:*** Black grams, Chick-peas, Soaking, Cooking, Carbohydrates, Starch.

## Introduction

Available and unavailable carbohydrates play an important role in human health. Available carbohydrates serve as a source of energy for human body whereas the importance of unavailable carbohydrates in normal and therapeutic diets has been well acknowledged in literature ( Spiller 1986; Morrow 1991; El-Bayoumy *et al* 1997). Unavailable carbohydrates which are commonly known as dietary fibre, mainly consist of cellulose, hemicellulose, lignin and pectin. These unavailable carbohydrates components exert different physiological effects on human health. Unavailable carbohydrates particularly pectin lower serum cholesterol help to reduce the risk of heart attack (Kelsey 1978). Presence of unavailable carbohydrates in diets is also helpful to prevent appendicitis, colon cancer and constipation in human due to absorption of water from the digestive track (Awan 1993; Hu Frank *et al* 2000; ). In diabetics, legumes are reported to reduce the level of glucose in human blood due to the presence of unavailable carbohydrates (Brand *et al* 1990).

Available and unavailable carbohydrates are present in various food legumes. Food legumes are usually cooked after soaking in water prior to consumption. Cooking process is known to improve the nutritional quality of legumes whereas most of the macro and micro-nutrients are lost during soaking and cooking process (De-Leon *et al* 1992; Addy *et al* 1995). However, very little information is available in literature regarding available and unavailable carbohydrates in raw and cooked legumes. Therefore, present study was undertaken to investigate the effect of soaking and cooking on available and unavailable carbohydrate in black grams (*Vigna mungo*) and chick-peas (*Cicer arietinum*). Starch digestibility of these legumes was also studied after soaking and cooking processes.

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## Materials and Methods

Black grams and chick-peas were obtained from Ayub Agricultural Research Institute, Resalewala, Faisalabad (Pakistan). These legumes were cleaned to remove broken seeds, dust and other foreign materials and then subjected to soaking treatments prior to cooking.

*Soaking treatment.* A 50g sample of legumes was soaked in 250ml of tap water (pH - 7.0) and sodium bicarbonate solution (1% w/v, pH - 9.5) separately at 30˚C and 100˚C for 1-2h. The soaking solution was drained off, rinsed twice with distilled water and then dried in a hot air oven (Horizontal Forced Air Drier, Proctor and Schwartz Inc. Philadelphia, PA) at 55˚C for 24h. Presoaked legumes were cooked in a pressure cooker as given below.

*Pressure cooking.* Presoaked legumes were placed in one liter beakers containing tap water (5ml/g). Tops of the beakers were covered with aluminium foil. After cooking in a pressure cooker at 15 lbs/inch$^2$ for 15 min, excess water was drained off and then dried in a hot air oven at 55˚C for 24h. Raw and processed legumes were ground in a Wiley Mill to pass through a 40 mesh sieve.

*Chemical analysis.* The total water soluble sugars were extracted according to the method of Cerning & Guilbot (1973). Starch was extracted from the sugar free pellet by the method of Clegg (1956). Quantitative determination of total soluble sugars and starch was carried out according to the method of Yemm and Willis (1954). Reducing sugars were estimated by Somogyi's modified method (Somogyi 1945), and non-reducing sugars were estimated by calculating the difference between total soluble sugars and reducing sugars. Unavailable carbohydrates including neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose, hemicellulose and lignin contents were estimated according to the method of Van Soest & Wine (1967) and Mc Queen & Nicholson (1979). In accordance with ealier researchers, a preliminary overnight incubation with bacterial alpha amylase was employed. This methodology had already been used by earlier workers for estimation of dietary fibre components in legumes (Vidal-Valverde & Frias 1991). *In vitro* starch digestibility was determined after digestion with pancreatic $\alpha$ amylase in 0.1M phosphate buffer at 37˚C for 2h. (Costas 1982). All determination were carried out in triplicate and standard deviation (SD) were calculated according to the method of Steel & Torrie (1980). Duncans multiple range test was used to determine significant differences ($P < 0.05$).

## Results and Discussion

Table 1 summarizes the available carbohydrates contents of raw and soaked black grams and chick-peas.Total soluble sugars, reducing sugars, non-reducing sugars and starch contents in black grams and chick peas were 9.64 and 9.83%, 0.78 and 0.83%, 8.86 & 9.00% and 42.95 and 44.33% respectively. Results in Table 1 show that soaking of black grams and chick-peas decreased the quantity of availabale carbohydrates i.e. total soluble sugars, reducing sugars, non-reducing sugars. When the soaking temperature and time was increased, the extent of decrease in all these carbohydrates became more pronounced in these legumes. Sodium bicarbonate solution, as soaking solution, the extent of loss was significantly ($P < 0.05$) higher than that observed when these legumes were soaked in tap water. It is apparent from Table 1 that water soaking process caused reductions in total soluble sugars from 4.46 - 19.29% from black grams and 5.90 - 21.56% from chick-peas whereas 14.41 - 34.33% and 15.36 - 32.96% total soluble sugars contents were reduced from black grams and chick-peas respectively, on soaking in sodium bicarbonate solution. Reduction in reducing and non-reducing sugars from these legumes on soaking in tap water and sodium bicarbonate solution were also observed. Starch contents of black grams and chick-peas were reduced from 6.86 - 14.94% and 5.07-11.45% respectively, due to water soaking process. However, starch contents were further reduced from 14.43 - 29.68% and 13.28 - 24.92% from black grams and chick-peas respectively, as a result of soaking these legumes in alkaline solution of sodium bicarbonate. In fact, reduction in the levels of available carbohydrates with these treatments occurred mainly because of their solubility in simple water and sodium bicarbonate solution which has already been observed by earlier workers in case of other dry beans (Silva and Braga 1982; Sudesh *et al* 1986). Generally, legume starch is composed of soluble and insoluble portions and the soluble portion might have been extracted out and consequently caused significant reduction in starch contents.

Available carbohydrates contents of black grams and chick-peas were further decreased as a result of cooking (Table 2). Cooking process caused reduction in total soluble sugars 28.43 - 59.64% and starch contents 30.50 - 67.40% from black grams whereas, 28.88 - 55.55% total soluble sugars and 29.93 - 63.40% starch contents were lost from chick-peas. It is evident from these findings that when soaking in water or sodium bicarbonate solution was combined with cooking, the extent of losses of available carbohydrates from these legumes was significantly ($P < 0.05$) higher in comparison to that of simple soaking treatment. This is understandable again based on the fact that, in boiling water during cooking, the solubility of sugars will comparatively be much higher than at ordinary temperature. Contrary to these observations, Rao & Belavady (1978) reported that cooking brought about a significant increase in soluble sugars. This could be explained by the fact that cooking water was not discarded in that study whereas soaking and cooking water was rejected and beans alone were analyzed for various carbohydrates components during the present study.

Table 3 summarizes the contents of unavailable carbohydrates contents of raw, soaked and cooked black grams and chick-peas. NDF, ADF, cellulose, hemicellulose and lignin contents in raw black grams and chick peas were 24.41 and 25.58%, 11.67 and 9.44%, 9.78 and 8.29%, 12.74 and 16.14%

**Table 1**

Effect of soaking on available carbohydrates contents (%)* of black grams and chick-peas

| Soaking conditions | | | Black grams | | | | Chick-peas | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Soaking solution | Temp. (°C) | Time (hr) | Reducing sugars | Non reducing sugars | Total soluble sugars | Starch | Reducing sugars | Non reducing sugar | Total soluble sugars | Starch |
| Raw | - | - | 0.78$^{a}$ ± 0.02 | 8.86$^{a}$ ± 0.36 | 9.64$^{a}$ ± 0.66 | 42.95$^{a}$ ± 1.7 | 0.83$^{a}$ ± 0.02 | 9.00$^{a}$ ± 0.22 | 9.83$^{a}$ ± 1.12 | 44.33$^{a}$ ± 1.72 |
| Tap water | 30 | 1 | 0.75$^{a}$ ± 0.02 | 8.46$^{a}$ ± 0.29 | 9.21$^{a}$ ± 0.51 | 40.00$^{a}$ ± 1.3 | 0.78$^{a}$ ± 0.04 | 8.47$^{a}$ ± 0.19 | 9.25$^{a}$ ± 1.08 | 42.08$^{a}$ ± 1.84 |
| | 30 | 2 | 0.49$^{a}$ ± 0.03 | 7.73$^{b}$ ± 0.22 | 8.22$^{b}$ ± 0.44 | 37.00$^{b}$ ± 1.5 | 0.57$^{b}$ ± 0.03 | 7.77$^{b}$ ± 0.18 | 8.34$^{b}$ ± 1.07 | 40.11$^{b}$ ± 1.34 |
| | 100 | 1 | 0.60$^{a}$ ± 0.02 | 7.89$^{a}$ ± 0.37 | 8.49$^{a}$ ± 0.40 | 39.12$^{a}$ ± 1.8 | 0.76$^{a}$ ± 0.05 | 8.42$^{a}$ ± 0.17 | 9.18$^{a}$ ± 0.98 | 42.22$^{a}$ ± 1.28 |
| | 100 | 2 | 0.38$^{b}$ ± 0.05 | 7.40$^{b}$ ± 0.41 | 7.78$^{b}$ ± 0.32 | 35.50$^{b}$ ± 1.4 | 0.51$^{b}$ ± 0.04 | 7.20$^{b}$ ± 0.22 | 7.71$^{c}$ ± 0.92 | 39.25$^{b}$ ± 1.62 |
| 1.0%Sodium bicarbonate | 30 | 1 | 0.50$^{b}$ ± 0.04 | 7.75$^{a}$ ± 0.52 | 8.25$^{b}$ ± 0.32 | 36.75$^{b}$ ± 1.14 | 0.60$^{b}$ ± 0.04 | 7.72$^{a}$ ± 0.20 | 8.32$^{c}$ ± 0.89 | 38.44$^{b}$ ± 1.80 |
| solution | 30 | 2 | 0.30$^{c}$ ± 0.02 | 6.62$^{b}$ ± 0.44 | 6.92$^{c}$ ± 0.28 | 35.00$^{b}$ ± 1.2 | 0.40$^{c}$ ± 0.05 | 7.40$^{b}$ ± 0.24 | 7.80$^{c}$ ± 0.55 | 36.66$^{c}$ ± 1.26 |
| | 100 | 1 | 0.60$^{a}$ ± 0.04 | 7.27$^{a}$ ± 0.43 | 7.87$^{b}$ ± 0.21 | 34.88$^{b}$ ± 1.1 | 0.65$^{b}$ ± 0.04 | 7.20$^{a}$ ± 0.25 | 7.85$^{a}$ ± 0.48 | 36.05$^{c}$ ± 1.22 |
| | 100 | 2 | 0.33$^{c}$ ± 0.05 | 6.00$^{b}$ ± 0.38 | 6.33$^{c}$ ± 0.29 | 30.20$^{c}$ ± 1.0 | 0.28$^{c}$ ± 0.02 | 6.00$^{c}$ ± 0.07 | 6.28$^{c}$ ± 0.44 | 33.28$^{c}$ ± 1.30 |

*; Mean values ± S.D., n = 3 (dry weight basis). Mean values within a column with the different superscripts are a,b,c significantly different at $P < 0.05$

**Table 2**

Effect of cooking process on available carbohydrates contents (%)* of soaked black grams and chick-peas

| Soaking conditions | | | Black Grams | | | | Chick-peas | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Soaking solution | Temp. (°C) | Time (hr) | Reducing sugars | Non reducing sugars | Total soluble sugars | Starch | Reducing sugars | Non reducing sugars | Total soluble sugars | Starch |
| Raw | - | - | 0.78$^{c}$ ± 0.05 | 8.86$^{a}$ ± 0.35 | 9.64$^{a}$ ± 0.45 | 42.95$^{a}$ ± 1.65 | 0.83$^{a}$ ± 0.06 | 9.00$^{a}$ ± 0.82 | 9.83$^{a}$ ± 1.75 | 44.33$^{a}$ ± 1.05 |
| Tap water | 30 | 2 | 0.35$^{b}$ ± 0.06 | 6.55$^{b}$ ± 0.27 | 6.90$^{b}$ ± 0.33 | 29.85$^{b}$ ± 1.79 | 0.42$^{b}$ ± 0.05 | 6.80$^{b}$ ± 0.72 | 7.22$^{b}$ ± 1.11 | 31.06$^{b}$ ± 0.57 |
| | 100 | 2 | 0.27$^{c}$ ± 0.01 | 5.73$^{b}$ ± 0.29 | 6.00$^{b}$ ± 0.32 | 27.11$^{b}$ ± 1.00 | 0.38$^{b}$ ± 0.06 | 5.93$^{b}$ ± 0.55 | 6.31$^{c}$ ± 0.92 | 30.15$^{b}$ ± 0.61 |
| 1.0%Sodium bicarbonate | 30 | 2 | 0.23$^{c}$ ± 0.02 | 4.00$^{c}$ ± 0.22 | 4.23$^{c}$ ± 0.24 | 19.65$^{c}$ ± 1.25 | 0.30$^{c}$ ± 0.04 | 5.25$^{b}$ ± 0.34 | 5.55$^{c}$ ± 0.82 | 20.56$^{c}$ ± 0.32 |
| solution | 100 | 2 | 0.14$^{d}$ ± 0.01 | 3.75$^{c}$ ± 0.22 | 3.83$^{c}$ ± 0.19 | 14.00$^{d}$ ± 1.35 | 0.22$^{d}$ ± 0.02 | 4.00$^{c}$ ± 0.32 | 4.22$^{c}$ ± 0.42 | 16.22$^{c}$ ± 0.40 |

*; Mean Values ± S.D., n = 3 (dry weight basis). Mean values within a column with the different superscripts a,b,c,d are significantly different at $P < 0.05$.

and 1.89 & 1.15% respectively. Soaking of black grams and chick-peas caused some changes in unavailable carbohydrates profile i.e. NDF, ADF, cellulose, hemicellulose and lignin. Soaking of these legumes in tap water did not significantly alter NDF, hemicellulose and lignin contents on dry matter basis. A slight but significant increase in ADF, (4.28% black grams, 3.49% chick-peas) and cellulose (5.01% black grams, 3.98% chick- peas) was observed (Table 3). Soaking in 1% sodium bicarbonate solution caused a sharp increase in hemicellulose (54.31% black grams, 42.50% chick-peas), cellulose increase slightly (6.44% black grams, 6.15% chick-peas) and lignin contents remained unchanged. As a result of increase in hemicellulose and cellulose, NDF and ADF contents of black grams and chick-peas also increased by 30.68 & 28.69% and 4.88 & 4.98% respectively. Earlier workers also reported, significant increase in hemicellulose during soaking of lentils in sodium bicarbonate solution at room temperature for 9h. (Vidal-Valverde *et al* 1992).

Cooking of presoaked black grams and chick-peas also brought about some changes in unavailable carbohydrates. Reduction in the amounts of cellulose from 12.88 - 28.42% and hemicellulose from 31.86 - 59.37% was observed from black grams whereas 15.56 - 33.05% cellulose and 33.02 - 50.24% hemicellulose contents were reduced from chick-peas on cooking (Table 3). However, lignin contents were distinctly increased on cooking these legumes. It is apparent from these findings that the reduction in hemicellulose contents were almost two times more than those for cellulose contents. Similarly, hemicellulose and cellulose contents were greatly reduced on cooking the alkali soaked legumes compared to water soaked legumes. Reduction in cellulose and hemicellulose could be attributed to chemical degradation of cellulose in glucose, hemicellulose into arabinose, xylose and galactose as a result of cooking (Robinson & Lawler 1986). These results are in consistent with the findings of Vidal-Valverde & Frias (1991), who found that hemicellulose contents in kidney beans were

**Table 3**

Unavailable carbohydrates contents (%)* in raw, soaked and cooked black grams and chick-peas

| Treatments | Black grams | | | | | Chick-peas | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NDF | ADF | Cellulose | Hemicellulose | Lignin | NDF | ADF | Cellulose | Hemicellulose | Lignin |
| Raw | 24.41$^{a}$±1.26 | 11.67$^{a}$±0.76 | 9.78$^{a}$±0.88 | 12.74$^{a}$±1.01 | 1.89$^{a}$±0.36 | 25.58$^{a}$±1.09 | 9.44$^{a}$±0.70 | 8.29$^{a}$±0.35 | 16.14$^{a}$±0.81 | 1.15$^{a}$±0.25 |
| Soaking process (100°C-2h) | | | | | | | | | | |
| Tap water | 24.95$^{a}$±1.22 | 12.17$^{a}$±0.66 | 10.27$^{a}$±0.70 | 12.78$^{a}$±0.83 | 1.90$^{a}$±0.22 | 25.93$^{a}$±1.18 | 9.77$^{a}$±0.60 | 8.62$^{a}$±0.52 | 16.16$^{a}$±0.73 | 1.15$^{a}$±0.22 |
| Sodium bicarbonate solution (1% w/v) | 31.90$^{b}$±1.21 | 12.24$^{a}$±0.60 | 10.41$^{a}$±0.61 | 19.66$^{b}$±0.52 | 1.83$^{a}$±0.32 | 32.92$^{b}$±1.01 | 9.92$^{b}$±0.42 | 8.80$^{b}$±0.50 | 23.00$^{b}$±0.49 | 1.12$^{b}$±0.25 |
| Cooking process after soaking in | | | | | | | | | | |
| Tap Water | 19.71$^{c}$±1.30 | 11.03$^{b}$±0.73 | 8.52$^{b}$±0.44 | 8.68$^{c}$±0.49 | 2.51$^{b}$±0.12 | 19.27$^{c}$±0.46 | 8.46$^{c}$±0.48 | 7.00$^{c}$±0.61 | 10.81$^{c}$±0.52 | 1.46$^{b}$±0.21 |
| Sodium bicarbonate solution (1% w/v) | 14.78$^{d}$±1.27 | 9.60$^{c}$±0.61 | 7.00$^{c}$±0.40 | 5.18$^{d}$±0.22 | 2.60$^{b}$±0.11 | 15.08$^{d}$±0.15 | 7.05$^{c}$±0.22 | 5.55$^{d}$±0.20 | 8.03$^{d}$±0.18 | 1.50$^{b}$±0.11 |

* Mean Values± S.D., n = 3 (dry weight basis). Mean values within a column with the different superscripts a,b,c,d are significantly different at P < 0.05

**Table 4**

Effect of soaking and cooking on starch digestibility (%)* of black grams and chick-peas

| Soaking conditions | | | Black grams | | Chick-peas | |
|---|---|---|---|---|---|---|
| Soaking solution | Temp. (°C) | Time (hr) | Without cooking | Pressure cooking | without cooking | Pressure cooking |
| Raw | - | - | 37.37$^{a}$ ± 1.32 | 45.67$^{a}$ ± 1.45 | 39.00$^{a}$ ± 1.27 | 46.77$^{a}$ ± 1.22 |
| Tap water | 30 | 2 | 41.00$^{a}$ ± 1.66 | 59.88$^{b}$ ± 1.49 | 42.80$^{b}$ ± 1.22 | 62.00$^{b}$ ± 1.74 |
| | 100 | 2 | 43.38$^{b}$ ± 1.72 | 64.00$^{b}$ ± 1.28 | 44.97$^{b}$ ± 1.41 | 65.50$^{b}$ ± 1.60 |
| Sodium bicarbonate solution | 30 | 2 | 42.22$^{b}$ ± 1.54 | 72.61$^{c}$ ± 1.72 | 44.00$^{b}$ ± 1.08 | 74.11$^{c}$ ± 1.72 |
| | 100 | 2 | 44.00$^{b}$ ± 1.29 | 83.00$^{c}$ ± 1.80 | 45.89$^{b}$ ± 1.82 | 86.00$^{d}$ ± 1.46 |

* Mean values ± S.D., n = 3 (dry weight basis). Mean values within a column with the different superscripts a,b,c,d are significantly different at P < 0.05.

greatly decreased as a result of cooking. It is apparent from Table 3 that NDF contents decreased from 19.25 - 39.45% & 24.66 - 41.04% respectively, on cooking presoaked black grams and chick-peas. Similarly, decrease in ADF contents of black grams and chick-peas were 5.48 - 17.78% and 10.38 - 25.31%, respectively after cooking. These results revealed that reduction in NDF contents was comparatively higher than ADF contents. Data presented in Table 3, also showed that reductions in NDF and ADF contents were markedly higher on cooking the alkali soaked legumes. Reductions in NDF and ADF contents in cooked legumes could be attributed to partial degradation of cellulose and hemicellulose into simple sugars (Robinson and Lawler 1986; Rehman and Shah 1994). These results are in agreement with those obtained by Vidal-Valverde *et al* (1992) who reported distinct decrease in NDF due to a drastic loss in hemicellulose on cooking presoaked lentils.

Besides losses in available and unavailable carbohydrates, starch digestibility was affected significantly (P < 0.05) on cooking, whereas it remained almost unchanged after soaking in water or sodium bicarbonate solution as shown in Table 4. Initially, starch digestibility of uncooked black grams and chick-peas was 37.37% & 39.00% which became 45.67% & 46.77% respectively after cooking in a pressure cooker. Maximum increase in starch digestibility was found to be about 120% after cooking alkali soaked black grams and chick peas in a pressure cooker whereas the increase was only 68 - 71% on cooking water soaked legumes in a pressure cooker. Improvement in starch digestibility after cooking could be attributed due to complete hydrolysis of starch under the drastic conditions of heating under pressure. However, improvement in digestibility of starch become about two times more for alkali soaked legumes compared to water soaked legumes on cooking. These results are in agreement with those obtained by Mbofung *et al* (1999) who reported distinct improvement in starch digestibility of cow-peas after cooking. In this study, legumes were markedly resistant to pancreatic amylase attack but cooking led to a dramatic increase in its susceptibility to digest by this enzyme. In fact, cooking improves the digestibility of starch through gelatinization and destruction of anti-nutrients (Yu - Hui 1991).

## Conclusion

Available and unavailable carbohydrates contents of black grams and chick-peas were reduced to various extents due to soaking and cooking processes. Soaking temperatures and time significantly affected the rate of extraction of available and unavailable carbohydrates. Sodium bicarbonate solution extracted comparatively more carbohydrates compared to water soaking process. Maximum amount of available and unavailable carbohydrates were reduced as a result of cooking process. Besides losses in available and unavailable carbohydrates, significant improvement in starch digestibility of black grams and chick -peas was observed after cooking. However, no appreciable improvement in starch digestibility of black grams and chick-peas was observed after cooking. However, no sappreciable improvement in starch digestibility was observed after soaking these legumes in tap water and sodium bicarbonate solution.

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