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# Maternal effect associated to cooking quality of common bean

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**ABSTRACT** - *The cooking time of common bean grains is one of the determinant factors for the consumer acceptance of a cultivar. Since in the segregating populations tegument and cotyledons are in different generations, one needs to know which one of these structures influences the cooking quality to define breeding objectives. We evaluated the parentals, the $F_1$, $F_2$, and $F_3$ generations and the reciprocals of the crosses CI-107 x Carioca-80, CI-107 x Amarelinho and CI-107 x G2333. A maternal effect was stated in the trait expression since bean cooking quality was mainly determined by the tegument constitution. The inferences derived from genetic and phenotypic parameters were not expressively affected by storing, whereas the cooking time increased with higher grain ages.*

**Key words**: Common bean, genetic improvement, cooking time.

## INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is attractive for consumption from the nutritional standpoint due to components and substances that make it a remarkable source of proteins, fibers, vitamins, carbohydrates, and minerals. Moreover, it has phenolic compounds with antioxidant action that can reduce disease incidence (Beninger and Hosfield 2003). This legume is part of the daily diet of the Brazilian population, in longstanding cultivation in most Brazilian states, practically all year round (CONAB 2004).

In common bean improvement programs, in some moment lines are inevitably evaluated for cooking time, which is one of the factors of utmost importance for the consumer acceptance of a cultivar. The trait has been studied for some time. Genetic variation between the lines was stated (Elia et al. 1997, Jacinto-Hernandez et al. 2003). The effects of environmental factors such as drying and storage time were also observed (Carbonell et al. 2003, Boros and Wawer 2004).

Several factors have been investigated to obtain information on the difference in the cooking time of some lines (Elia et al. 1997, Costa et al. 2001, Jacinto-Hernandez et al. 2003). There are however still doubts about whether the trait depends only on properties associated to the tegument and/or the cotyledons. This information is fundamental in improvement programs since the two are in different generations. The reason is that tegument is maternal tissue and the cotyledons are a product of fecundation and therefore have xenia effect (Ramalho et al. 2004).

The present study was conducted to verify which of the grain constituents has an influence on cooking time, to compile information on the genetic control of

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this trait and to find out if storage time has an effect on how grain constituents influence the cooking quality.

## MATERIAL AND METHODS

Seeds of four common bean lines of the germplasm bank of the Universidade Federal de Lavras were used, previously evaluated for water absorption and cooking time (Costa et al. 2001). Line CI-107 and Carioca-80 both have beige, opaque, carioca type grains with brown stripes of average size, and growth habit type III. They differ regarding the cooking time, which is shorter in the former and longer in the latter, besides a yellow halo on Carioca-80 grains. Line Amarelinho produces small shiny yellow grains, with growth habit type III and a longer cooking time. Line G2333 has shiny red grains of average size, growth habit type IV and a longer cooking time. All four have a 90-day cycle and prostrate habit.

In a methodology similar to the one presented by Ramalho et al. (1993), the following biparental crosses were performed: CI-107 ($P_1$) x Carioca-80 ($P_2$), CI-107 ($P_1$) x Amarelinho ($P_3$), CI-107 ($P_1$) x G2333 ($P_4$) and the respective reciprocals. The $F_1$ seeds and respective reciprocals were sown in a greenhouse to obtain the $F_2$ generation. Simultaneously the $F_1$ seeds were obtained again to get $F_1$ and $F_2$ seeds of the same age. In the following generation, part of the $F_2$ seeds of each cross were sown to develop the $F_3$ generation under field conditions. The process was repeated to have grains of the same age available.

At all post-harvest stages the grains were sun-dried to a moisture of approximately 13%. Then they were wrapped in paper bags and stored under at room temperature until the evaluation. The evaluation periods and the generations involved in the cooking test are presented in Table 1, in 10 replications for each generation in the evaluation periods.

For the evaluation of the cooking quality each grain was placed separately in a recipient with distilled water and after 18 hours cooked in a JAB-77 experimental cooker, small type, to measure the cooking time, according to a methodology adapted from Proctor and Watts (1987). The cooker has 25 spikes, one per grain. The cooker, equipped with the grains, was placed in a beaker with 1,000 ml boiling water that was kept hot on a hotplate with a constant surface temperature of 300 ºC. The time from the beginning of the cooking process until the moment when the spike pierced each bean grain was considered the cooking time per grain.

The cooking time of each grain, in minutes, was subjected to the analysis of variance per evaluation period and then to a joint analysis of the periods for each cross and generation. With the underlying data means obtained in each cross and generation type, the mean components were estimated using the following model that was based on the generation of the cotyledons.

$Y = m + a + d + e$, where:

Y: mean cooking time of the population in each period;
m: mean of the completely contrasting homozygous parents
a: evaluation of the maternal effect ($F_1$ generation) and contribution of the homozygous loci ($F_2$ and $F_3$ generations)
d: contribution of the heterozygous loci (dominance effect)
e: effect of the evaluation period

## RESULTS AND DISCUSSION

Foremost, it must be emphasized that the cotyledons in a seed are products of fecundation, whereas the tegument is maternal tissue. Thus, these tissues are in different generations. To prevent any doubts about the interpretation of the identification of the generations in the present study, the generation of the embrionary axis or cotyledons was used as reference. Each generation was represented by two numbers; the first identified the generation itself and the second the parent used as female.

To conduct a study of this nature, particularly since the $F_2$ generation is involved, it is necessary to evaluate the grains individually. This fact contributed to a high coefficient of variation (CV) which varied from 24.9 to 34.6%. In the literature no data were found of evaluations of individual cooking of common bean grains. There are, however, countless results of evaluations involving lines or families, using mean data of different grains. In this case, the CV estimate is more suitable (Elia et al. 1997, Costa et al. 2001).

As expected the mean results (Table 2) showed that after a longer storage period the cooking time was longer. The periods x populations interaction was

**Table 1**.Number of grains used in the evaluation of the cooking time of the cross between CI-107 ($P_1$), Carioca-80 ($P_2$), Amarelinho ($P_3$) and G2333 ($P_4$) and the respective reciprocals in the $F_1$, $F_2$ and $F_3$ generations in three evaluation periods

| Evaluations[2] | Generations | Nr. of individuals | Generations | Nr. of individuals |
|---|---|---|---|---|
| | $P_1$ – CI-107 | 5 | | |
| | $P_2$ – Carioca-80 | 4 | | |
| | $P_3$ – Amarelinho | 2 | | |
| | $P_4$ – G2333 | 2 | | |
| | $F_{11}$[1] - ♀ CI-107 x Carioca-80 | 2 | | |
| 1ª | $F_{12}$ - ♀ Carioca-80 x ♂ CI-107 | 2 | | |
| | $F_{11}$ - ♀ CI-107 x ♂ Amarelinho | 2 | | |
| | $F_{13}$ - ♀ Amarelinho x ♂ CI-107 | 2 | | |
| | $F_{11}$ - ♀ CI-107 x ♂ G2333 | 2 | | |
| | $F_{14}$ - ♀ G2333 x ♂ CI-107 | 2 | | |
| | Total | 25 | | |
| 2ª | $P_1$ - CI-107 | 4 | $P_1$ – CI-107 | 4 |
| | $P_2$ - Carioca-80 | 4 | $P_2$ – Carioca-80 | 4 |
| | $F_{12}$ - ♀ Carioca-80 x ♂ CI-107 | 4 | $F_{11}$ -♀ CI-107 x ♂ Carioca-80 | 4 |
| | $F_{22}$ -♀ Carioca-80 x ♂ CI-107 | 13 | $F_{21}$ -♀ CI-107 x ♂ Carioca-80 | 13 |
| | Total | 25 | Total | 25 |
| 2ª | $P_1$ – CI-107 | 4 | $P_1$ – CI-107 | 4 |
| | $P_3$ – Amarelinho | 4 | $P_3$ – Amarelinho | 4 |
| | $F_{13}$ - ♀ Amarelinho x ♂ CI-107 | 4 | $F_{11}$ ♀ CI-107 x ♂ Amarelinho | 4 |
| | $F_{23}$ - ♀ Amarelinho x ♂ CI-107 | 13 | $F_{21}$ ♀ CI-107 x ♂ Amarelinho | 13 |
| | Total | 25 | Total | 25 |
| 2ª | $P_1$ - CI-107 | 4 | $P_1$ – CI-107 | 4 |
| | $P_4$ - G2333 | 4 | $P_4$ – G2333 | 4 |
| | $F_{14}$ -♀ G2333 x ♂ CI-107 | 4 | $F_{11}$ - ♀ CI-107 x ♂ G2333 | 4 |
| | $F_{24}$ -♀ G2333 x ♂ CI-107 | 13 | $F_{21}$ - ♀ CI-107 x ♂ G2333 | 13 |
| | Total | 25 | Total | 25 |
| 3ª | $P_1$ - CI-107 | 2 | $P_1$ – CI-107 | 2 |
| | $P_2$ -Carioca-80 | 2 | $P_2$ – Carioca-80 | 2 |
| | $F_{22}$ -♀ Carioca-80 x ♂ CI-107 | 10 | $F_{21}$ - ♀ CI-107 x ♂ Carioca-80 | 10 |
| | $F_{32}$ - ♀ Carioca-80 x ♂ CI-107 | 11 | $F_{31}$ - ♀ CI-107 x ♂ Carioca-80 | 11 |
| | Total | 25 | Total | 25 |
| 3ª | $P_1$ - CI-107 | 2 | | |
| | $P_3$ - Amarelinho | 2 | | |
| | $F_{23}$ - ♀ Amarelinho x ♂ CI-107 | 10 | | |
| | $F_{33}$ -♀ Amarelinho x ♂ CI-107 | 11 | | |
| | Total | 25 | | |
| 3ª | $P_1$ - CI-107 | 2 | | |
| | $P_4$ - G2333 | 2 | | |
| | $F_{24}$ -♀ G2333 x ♂ CI-107 | 10 | | |
| | $F_{34}$ -♀ G2333 x ♂ CI-107 | 11 | | |
| | Total | 25 | | |

$F_{11}$ – the first number refers to the generation and the second to the parent used as female
1st Evaluation in January 2003
2nd Evaluation in August 2003
3rd Evaluation in February 2004

**Table 2**. Mean cooking time, in minutes, obtained in the cross of CI-107 x Carioca-80. CI-107 x Amarelinho, CI-107 x G2333 and the respective reciprocals in the $F_1$, $F_2$, and $F_3$ generations, in three evaluation periods. Period A, evaluated 65 days after harvest, in January 2003; period B, 96 days after harvest, in August 2003; and period C evaluated 112 days after harvest in February 2004

| Populations | Period A | Period B | Period C |
|---|---|---|---|
| $P_1$ – CI-107 | 26 | 44 | 38 |
| $P_2$ – Carioca-80 | 39 | 56 | 53 |
| $F_{11}$[1] ♀ CI-107 x ♂ Carioca-80 | 32 | 35 | - |
| $F_{12}$ - ♀ Carioca-80 x ♂ CI-107 | 35 | 52 | - |
| $F_{21}$ - ♀ CI-107 x ♂ Carioca-80 | - | 54 | 47 |
| $F_{22}$ - ♀ Carioca-80 x ♂ CI-107 | - | 52 | 48 |
| $F_{31}$ - ♀ CI-107 x ♂ Carioca-80 | - | - | 51 |
| $F_{32}$ - ♀ Carioca-80 x ♂ CI-107 | - | - | 56 |
| $P_1$ – CI-107 | 26 | 34 | 36 |
| $P_3$ – Amarelinho | 33 | 50 | 47 |
| $F_{11}$ - ♀ CI-107 x ♂ Amarelinho | 28 | 34 | - |
| $F_{13}$ - ♀ Amarelinho x ♂ CI-107 | 46 | 41 | - |
| $F_{21}$ - ♀ CI-107 x ♂ Amarelinho | - | 40 | - |
| $F_{23}$ - ♀ Amarelinho x ♂ CI-107 | - | 57 | 44 |
| $F_{33}$ - ♀ Amarelinho x ♂ CI-107 | - | - | 50 |
| $P_1$ – CI-107 | 24 | 35 | 34 |
| $P_4$ – G2333 | 31 | 51 | 52 |
| $F_{11}$ - ♀ CI-107 x ♂ G2333 | 25 | 37 | - |
| $F_{14}$ - ♀ G2333 x ♂ CI-107 | 33 | 51 | - |
| $F_{21}$ - ♀ CI-107 x ♂ G2333 | - | 31 | - |
| $F_{24}$ - ♀ G2333 x ♂ CI-107 | - | 42 | 54 |
| $F_{34}$ - ♀ G2333 x ♂ CI-107 | - | - | 54 |

[1] $F_{11}$ – the first number refers to the generation and the second to the female parent

significant. Note for instance, that in the cross CI- 107 x Carioca-80 in the $F_1$ population cooking time was very similar in the two periods while for the parents and $F_2$ the difference was more expressive. These results agree with several other reports in the literature (Carbonell et al. 2003, Boros and Wawer 2004). One of the reasons is that the lignin content in stored beans is higher that in young beans. Estimates evidenced that it varies from 8.4 g $100g^{-1}$ in recently harvested beans to 13 g 100g $^{-1}$ dry matter in stored common bean.

Furthermore, divergence was observed between the parents (Table 2), which is fundamental to test the formulated hypotheses. Line CI-107 is cooked faster and the lines Amarelinho, Carioca-80 and G2333 cook slower. Our results confirm previous evaluations involving these lines (Costa et al. 2001). The performance of the parents in relation to the $F_1$ and reciprocal generation is noteworthy. In most situations the mean of the $F_1$ generation was similar to that of the parent used as female (Tables 2 and 3). Preliminarily, the inference was drawn that cooking time does not depend on the cotyledons, i.e., depends on the tegument only.

The estimates of the mean components involving the parents and $F_1$ generations of the three crosses are presented in Table 5. In this case, component $\underline{a}$ expressed the difference in the reciprocal effects. The estimate of $\underline{a}$ was significant in all cases. Interestingly the estimate of $\underline{d}$, on the contrary, was not significant, confirming that cooking time is predominantly determined by the tegument constitution. To confirm these previous observations, a similar procedure of analysis was adopted for the $F_2$ generations (means

**Table 3**. Estimate of the probability (P) obtained in the F test, for a comparison of the contrasts of the crosses of the parents CI-107 ($P_1$) and Carioca-80 ($P_2$), CI-107 ($P_1$) and Amarelinho ($P_3$) and CI-107 ($P_1$) and G2333 ($P_4$) and the reciprocals in the $F_1$ and $F_2$ generation, in the two evaluated periods. Period A, evaluated 65 days after harvest, in January 2003; and period B, 96 days after harvest, in August 2003

| Contrasts | Period A | Period B |
|---|---|---|
| $P_1$ vs $P_2$ | 0.0001 | 0.1306 |
| $P_1$ vs $F_{11}$[1] | 0.0648 | 0.2396 |
| $P_2$ vs $F_{12}$ | 0.2906 | 0.8862 |
| $F_{11}$ vs $F_{12}$ | 0.2347 | 0.0001 |
| $P_1$ vs $F_{21}$ | - | 0.1750 |
| $P_1$ vs $F_{22}$ | - | 0.2567 |
| $P_2$ vs $F_{21}$ | - | 0.7601 |
| $P_2$ vs $F_{22}$ | - | 0.5788 |
| $F_{21}$ vs $F_{22}$ | - | 0.5742 |
| $P_1$ vs $P_3$ | 0.0188 | 0.0051 |
| $P_1$ vs $F_{11}$ | 0.5086 | 0.9287 |
| $P_3$ vs $F_{13}$ | 0.0001 | 0.0718 |
| $F_{11}$ vs $F_{13}$ | 0.0001 | 0.0210 |
| $P_1$ vs $F_{21}$ | - | 0.0082 |
| $P_1$ vs $F_{23}$ | - | 0.0001 |
| $P_3$ vs $F_{21}$ | - | 0.7001 |
| $P_3$ vs $F_{23}$ | - | 0.3223 |
| $F_{21}$ vs $F_{23}$ | - | 0.0011 |
| $P_1$ vs $P_4$ | 0.0519 | 0.0001 |
| $P_1$ vs $F_{11}$ | 0.5513 | 0.6425 |
| $P_4$ vs $F_{14}$ | 0.6237 | 0.9568 |
| $F_{11}$ vs $F_{14}$ | 0.0015 | 0.0001 |
| $P_1$ vs $F_{21}$ | - | 0.0034 |
| $P_1$ vs $F_{24}$ | - | 0.0013 |
| $P_4$ vs $F_{21}$ | - | 0.5843 |
| $P_4$ vs $F_{24}$ | - | 0.8314 |
| $F_{21}$ vs $F_{24}$ | - | 0.3702 |

[1] $F_{11}$ – the first number refers to the generation and the second to the female parent

presented in Table 2 and significance of contrasts in Table 3). The most expressive result is the mean performance of the $F_{2i}$ and $F_{2j}$ generations, which was very similar in the two periods and the mean of the periods. The estimates of the different contrasts reinforced this observation. The contrast $F_{2i}$ vs $F_{2j}$ was not significant in any of the conditions except for cross CI-107 ($P_1$) x Amarelinho ($P_3$).

The estimates of the mean components involving the $F_2$ generation are presented in Table 5. The model considered cooking time as dependent of the tegument constitution and that the $F_2$ generation therefore has a tegument constitution due to the genotype of the $F_1$ plant. The results obtained are compatible with this observation, especially since the adopted model explained nearly all variation, as the high $R^2$ estimates show. Furthermore, dominance was inferred in the trait expression (Table 5).

In general, the mean results of the analyses of the parents and $F_3$ generation for the three crosses are in line with the previous results (Table 2). Most of the contrasts involving the generations were significant

**Table 4**. Estimate of the probability (P) obtained in the F test, for comparison of the contrasts of the crosses of the parents CI-107 ($P_1$) x Carioca-80 ($P_2$), CI-107 ($P_1$) x Amarelinho ($P_3$) and CI-107 ($P_1$) x G2333 ($P_4$) and the reciprocals in the $F_2$ and $F_3$ generations in the evaluation period C, 112 days after harvest

| Contrasts | Period C |
|---|---|
| $P_1$ vs $P_2$ | 0.0003 |
| $P_1$ vs $F_{21}$ [1/] | 0.0234 |
| $P_1$ vs $F_{22}$ | 0.0088 |
| $P_1$ vs $F_{31}$ | 0.0003 |
| $P_1$ vs $F_{32}$ | 0.0001 |
| $P_2$ vs $F_{21}$ | 0.0437 |
| $P_2$ vs $F_{22}$ | 0.1059 |
| $P_2$ vs $F_{31}$ | 0.4598 |
| $P_2$ vs $F_{32}$ | 0.3035 |
| $F_{21}$ vs $F_{22}$ | 0.6237 |
| $F_{21}$ vs $F_{31}$ | 0.0616 |
| $F_{21}$ vs $F_{32}$ | 0.0001 |
| $F_{22}$ vs $F_{31}$ | 0.1861 |
| $F_{22}$ vs $F_{32}$ | 0.0007 |
| $F_{31}$ vs $F_{32}$ | 0.0082 |
| $P_1$ vs $P_3$ | 0.1346 |
| $P_1$ vs $F_{23}$ | 0.1848 |
| $P_1$ vs $F_{33}$ | 0.0242 |
| $P_3$ vs $F_{23}$ | 0.5644 |
| $P_3$ vs $F_{33}$ | 0.5655 |
| $F_{23}$ vs $F_{33}$ | 0.0196 |
| $P_1$ vs $P_4$ | 0.0102 |
| $P_1$ vs $F_{24}$ | 0.0013 |
| $P_1$ vs $F_{34}$ | 0.0006 |
| $P_4$ vs $F_{24}$ | 0.5972 |
| $P_4$ vs $F_{34}$ | 0.5018 |
| $F_{24}$ vs $F_{34}$ | 0.8961 |

$F_{11}$ – the first number refers to the generation and the second to the female parent

(Table 4), evidencing the occurrence of dominance. Since dominance occurred in the sense of a longer cooking time, it was expected that the mean of the $F_3$ generation would be lower than of $F_2$. The opposite was true. The reason is probably due to sampling problems, namely in the $F_3$ generation. These results are not in line with the previously reported. It is however noteworthy that the estimates of the genetic additive component (a) and especially of dominance (d), involving one of the crosses (CI-107 ($P_1$) and Carioca-80 ($P_2$) were not significant (Table 5). This result allows the conclusion that the inbreeding depression cited in the comparison of the $F_2$ and $F_3$ generations can be attributed to sampling problems in these generations, as mentioned above.

The results obtained with the three crosses allowed the conclusion that cooking time is predominantly a function of the tegument. The reason is that the $F_1$ seed performance for cooking time was always the same as of the female parent. The performance of the $F_2$ and $F_3$ generations as well as the results for the estimates of the mean components, especially the contribution of the loci in heterozygosis, reinforced this observation. Note that when only grains of the $F_1$ generation and parents were used, the contribution of this component was zero in the trait expression. However, when the $F_2$ generation of the embryo and $F_1$ of the tegument was involved, this component was different from zero. The trait expression depended on the genetic constitution of the tegument and is therefore a maternal effect.

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# Efeito materno associado à capacidade de cozimento do feijão

**RESUMO** - *O tempo de cozimento dos grãos de feijão é um dos principais fatores envolvidos com a adoção de uma cultivar de feijão. Como o tegumento e os cotilédones estão em gerações diferentes quando da condução de populações segregantes, é indispensável identificar qual dessas estruturas afeta a cozimento e assim orientar os trabalhos de melhoramento.Foram avaliados os genitores, as gerações $F_1$, $F_2$, $F_3$ e seus recíprocos dos cruzamentos: CI-107 x Carioca-80, CI-107 x Amarelinho e CI-107 x G2333 e seus respectivos recíprocos. Constatou-se efeito materno na expressão do caráter, isso porque o tegumento foi o principal constituinte do grão de feijão responsável pelo cozimento. As inferências obtidas por meio dos parâmetros genéticos e fenotípicos não sofreram alterações expressivas com o decorrer do armazenamento, embora o tempo de cozimento incrementasse com a idade dos grãos.*

**Palavras-chave**: Feijão, melhoramento genético, tempo de cozimento.

**Table 5**. Estimate of the mean components for cooking time in minutes, of the cross of the lines CI-107 ($P_1$) x Carioca-80 ($P_2$) in the $F_1$, $F_2$ and $F_3$ generations in the three evaluation periods and of the crosses of CI-107 ($P_1$) x Amarelinho ($P_3$) and CI-107 ($P_1$) x G2333 ($P_4$) in the evaluation period of the reciprocals

| **Components** | **Parents. $F_{11}$ and $F_{12}$[1]** | **P** | **Parents. $F_{21}$ and $F_{22}$** | **P** | **Parents. $F_{31}$ and $F_{32}$** | **P** |
|---|---|---|---|---|---|---|
| m | 32.77 | 0.0002 | 50.68 | 0.0000 | 48.69 | 0.0009 |
| a | 4.96 | 0.0339 | 7.38 | 0.0002 | 8.77 | 0.1252 |
| d | 0.87 | 0.8005 | 2.14 | 0.0366 | 1.45 | 0.8150 |
| e | 11.52 | 0.0379 | -5.26 | 0.0022 | - | - |
| | $R^2$=0.9926 | | $R^2$=0.9998 | | $R^2$=0.9943 | |
| Components | **Parents. $F_{11}$ and $F_{13}$** | **P** | **Parents. $F_{21}$ and $F_{23}$** | **P** | | |
| m | 31.75 | 0.0003 | 42.00 | 0.1119 | | |
| a | 5.44 | 0.0288 | 8.00 | 0.4779 | | |
| d | 2.26 | 0.4942 | 10.90 | 0.4289 | | |
| e | 5.74 | 0.1289 | - | - | | |
| | $R^2$=0.9921 | | $R^2$=0.9943 | | | |
| Components | **Parents. $F_{11}$ and $F_{14}$** | **P** | **Parents. $F_{21}$ and $F_{24}$** | | | |
| m | 26.79 | 0.0000 | 43.00 | 0.1444 | | |
| a | 5.28 | 0.0035 | 8.00 | 0.0772 | | |
| d | 3.04 | 0.1509 | 6.51 | 0.1061 | | |
| e | 14.26 | 0.0011 | - | - | | |
| | $R^2$=0.9977 | | $R^2$=0.9999 | | | |

[1] $F_{11}$ – the first number refers to the generation and the second to the female parent

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