Adoption Determinants of Biofertilizer Technology for Soybean in Rainfed Area

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Abstract. The target of the Government of Indonesia (the GoI) for achieving soybean self-sufficiency in 2018-2020 makes some efforts for increasing soybean production requiring the increase of productivity, as well as harvest area, should be done. The rainfed area is an excellent potential for soybean cultivation area expansion in Indonesia. The area reaches 3.1 million ha in Indonesia with 413,000 ha are in South Sulawesi Province. It mostly does not use for soybean cultivation due to limited water availability. Cropping patterns in the rainfed area are paddy-fallow, paddy-corn, paddy-soybean, or paddy-mungbean depends on the water availability. The productivity of soybean in the rainfed area is around 1.5 t/ha, and it is expected to be increased in the range of 1.8-3.2 t/ha. Dissemination of biofertilizer technology for soybean in the rainfed area named “Biodetas” was conducted during the dry season of 2017 in Tompobulu Sub-district, Maros Regency, South Sulawesi Province. Components of “Biodetas” technology introduced include (1) the use of biofertilizer (Agrisoy), (2) the reducing of NPK fertilizer use, (3) the use of leaf fertilizer, as well as (4) the use of organic fertilizer. The dissemination scale was 40 ha then compared to 5 ha of the existing cultivation. Research aimed to determine factors affecting farmers to adopt the biofertilizer technology of “Biodetas”. Research used regression analyses using a binary logic model with the IBM SPSS Statistics 20 program. Variables used were farmers’ experience on soybean cultivation, formal education, the extent of soybean planting area, soybean production, income from soybean, rice, and other farming activities, as well as dummy variables for land ownership status, biofertilizer production inputs access, improved seed access, and higher production cost should be provided by farmers. The application of “Biodetas” was able to increase soybean yield to 2.7 t/ha, 71% higher compared to the existing technology that produced 1.6 t/ha soybean. It is economically feasible to be adopted by farmers with B/C ratio 1.2. The determinant of technology adoption by farmers was the extent of the soybean planting area. The larger soybean planting area will accelerate the adoption of technology. It may be related to landowners’ economic capability to provide the necessary production inputs to obtain the optimal yield.

1. Introduction
Soybean is one of food commodities that have an important and strategic role in Indonesia because it is a multi-purpose and multi-user commodity [1]. In 2016, national soybean needs reached around 2,500 thousand tons, while the production was only around 900 thousand tons. And in 2018, national soybean production is estimated to reach 1,334 thousand tons with consumption needs reaching 2,939 thousand tons so that there is still a shortage of around 1,605 thousand tons which must be met through imports [2].

The low capacity of national soybean production requires various efforts to narrow the gap, including through intensification in soybean production centers, extensification, and diversification that
rely on resources potential [3]. The high level of dependence on Indonesian food production to Java island until 60% creates a risky situation. This is because the agricultural area in Java will be more competitive to other food commodities that are more profitable and even some agricultural areas have been eroded along with land conversion to the non-agricultural sector. In 2015, the national soybean harvested area only reached 614 thousand ha with an average productivity of 1.57 t/ha [4], so as to achieve self-sufficiency in soybeans, the area of harvest must be expanded to around 1,800 thousand ha with an average productivity of 1.70 t/ha. Therefore, the expansion of soybean harvest area needs to be carried out to marginal lands, including non-productive land, dry land, rainfed area, and tidal swampland [5].

The potential of the rainfed area in Indonesia reaches 3,100 thousand ha, of which 413 thousand ha are in the Province of South Sulawesi [6]. However, most of the rainfed area has not been utilized for soybean farming. Cropping patterns that are widely applied by farmers in the rainfed area are rice-fallow, rice-corn, rice-soybeans, or rice-mung beans depending on the availability of water. According to Subandi and Anwari (2012), soybean productivity in the rainfed area in South Sulawesi Province can be increased from around 1.5 t/ha to 1.7-2.3 t/ha using improved varieties and improved cultivation techniques. Some research results show that soybean productivity in the rainfed area in Java can reach 1.8-3.2 t/ha depending on the type used and the input provided [7,8]. If soybean farming can be developed at least on 10% of the rainfed area with an average productivity of 2.0 t/ha, then the contribution of the area to national soybean production can reach 620 thousand t/year. This will undoubtedly contribute significantly to the efforts of increasing domestic soybean production towards self-sufficiency [9].

The package of soybean cultivation technology in rainfed area named “Biodetas” which emphasizes on biofertilizer technology includes: (1) the use of biofertilizer (Agrisoy), (2) the reducing of NPK fertilizer use, (3) the use of leaf fertilizer, as well as (4) the use of organic fertilizer. The method of N-fixing biofertilizer (Agrisoy) combined with P-solvent bacteria or mycorrhiza can improve soil fertility on land that has never been or rarely planted with soybean [10]. The Agrisoy application with organic fertilizer 1.0-1.5 t/ha in a paddy field, acid soil, and tidal land, saves the use of NPK fertilizer to 50% and soybean productivity can reach >2.0 t/ha.

At present, the introduction of many new technologies is considered to be less successful, indicated by the low level of adoption [11]. Ref. [12]) stated that the reduction in the adoption of new technologies was varied from partial adoption to returning to previous farmers’ cultivation technology (existing). It is caused by technical and socio-economic factors. The main technical factors in adopting new technologies are the improvement of soil and water quality as well as pest control. Meanwhile, the socio-economic factors are: (1) the urgency of technology to the needs of farmers, (2) the chance of harvest success, (3) the capital of farmers, (4) the adequacy of labor, (5) the quality of agricultural service institutions (farmers group, village cooperative, extension service, and marketing), (6) the ease of obtaining input, (7) the support and attention from local government officials, and (8) the product marketing system [13]. Technically and financially, the “Biodetas” soybean cultivation technology package can increase soybean productivity. However, it does not always meet the needs of farmers and will be further adopted by farmers. Therefore, this study aimed to determine factors affecting farmers to adopt the biofertilizer technology of “Biodetas”.

2. Materials and Methods
The study of adoption determinants of biofertilizer technology for soybean in the rainfed area named “Biodetas” was conducted in Tompobulu Village, Tompobulu Sub-district, Maros Regency, South Sulawesi Province during the dry season of 2017, from May to August involving 40 soybean farmers as respondents. The study is a part of technical research of “Development of Soybean Cultivation Technology in Rainfed Area”. The technology components of “Biodetas” in the rainfed area include: (1) the use of biofertilizer (Agrisoy), (2) the reducing of NPK fertilizer use, (3) the use of leaf fertilizer, as well as (4) the use of organic fertilizer (Table 1). The scale of “Biodetas” dissemination was 40 ha, which then was compared to 5 ha of the existing using farmers cultivation technology.

Primary data was obtained through a survey using structured questionnaires. The primary data is complemented by studying related literature. Data collected include (1) general characteristics of
farmers as respondents, (2) soybean farming experience; (3) financial analysis of soybean farming; (4) farmer’s households income; and (5) factors that determine the adoption of biofertilizer technology. The data obtained were analyzed descriptively quantitative and qualitative.

Factors determining the adoption of biofertilizer technology were analyzed by regression using a binary logistic model. The analysis used the IBM SPSS Statistics 20 program. The logit model formula is:

\[
P_i = \alpha + \sum_{i=1}^{n=5} \beta_i X_i + \sum_{i=1}^{n=4} \gamma_i D_i + \varepsilon_i
\]

Where:

\( P_i = 1 \) (if farmers are interested in adopting biofertilizer technology); \( 0 \) (if farmers are not interested in adopting biofertilizer technology)

\( \alpha \) = intercept

\( X_i \) = variable i

\( D_i \) = dummy of variable i

Table 1. Components of biofertilizer technology for soybean “Biodetas” in rainfed area of Tompobulu, Maros Regency, South Sulawesi in the dry season of 2017 (May to August)

| No. | Technology components | Soybean cultivation technology | Existing (Farmers’ technology) |
|-----|-----------------------|-------------------------------|--------------------------------|
| 1.  | Land preparation      | Without land preparation, straws cut 1-3 cm above the ground, spread as mulch | Without land preparation, straws cut 1-3 cm above the ground, spread as mulch |
| 2.  | Drainage channels     | Made every 3-4 m with a width and depth of channels of about 30 cm | Made every 3-4 m with a width and depth of channels of about 30 cm |
| 3.  | Pre-grown herbicide   | Apply 2-3 days before planting | Not applied |
| 4.  | Seed preparation      | Use quality seeds with growth viability >80% | Use quality seeds with growth viability >80% |
| 5.  | Planting              | 2-3 seeds/hole                | 2 seeds/hole |
| 6.  | Varieties             | Anjasmor*)                    | Anjasmor *) |
| 7.  | Planting time         | 4-7 days after rice harvesting “Tugal”***) | 4-7 days after rice harvesting “Tugal”***) |
| 8.  | Planting ways         | “Tugal”***)                   | 40 cm x 15 cm |
| 9.  | Plant spacing         | 40 cm x 15 cm                 | Not applied |
| 10. | Seed treatment        | Agrisoy***) 200 grams/50 kgs of seed/ha mixed with wet seeds during planting | Not applied |
| 11. | NPK fertilizer        | 200 kgs/ha Phonska + 50 kgs /ha SP 36 | 250 kgs/ha Phonska + 75 kgs/ha SP 36 |
| 12. | Liquid/ leaf fertilizer | Sprayed at 20 and 40 days after planting | Not applied |
| 13. | Organic fertilizer    | Dosage 1000 kgs/ha as a cover for planting holes | Not applied |
| 14. | Pests and diseases controlling | IPM, pests and diseases are sprayed with chemical pesticides when the threshold has been reached | IPM, pests and diseases are sprayed with chemical pesticides when the threshold has been reached |
| 15. | Irrigation            | Once at around 20 days after planting | Once at around 20 days after planting |
| 16. | Harvesting            | At physiological mature stage Thresher | At physiological mature stage Thresher |
| 17. | Post harvesting       |                              |                              |
Notes:
*) The soybean variety officially released by Indonesian Agricultural Assessment and Research Institute (IAARD) in 2001
**) “Tugal” means making a seed hole in the ground using a pointed stick
***) Agrisoy is biofertilizer produced by Indonesian Legumes of Tuber Crops Research Institute (Iletri) consisted of Rhizobium sp. as bioactive compound

Variables used were: (1) X1= farmers’ experience on soybean cultivation, (2) X2= formal education, (3) X3= the extent of soybean planting area, (4) X4= soybean production, (5) X5= income from soybean, rice, and other farming activities, as well as dummy variables for (1) D1= land ownership status (1= self-owned, 0= profit sharing), D2= consideration on biofertilizer production input access (1= considered, 0= not considered), D3= consideration on improved seed access (1= considered, 0= not considered), and D4= consideration on higher production cost should be provided by farmers (1= considered, 0= not considered).

3. Results and Discussion

3.1. General characteristics of farmer respondents
The differences in level technology mastery level were caused by the differences inherent in farmers such as farming experience, age, education as well as the external factors such as agricultural extension [14]. The age of 97.5% farmer respondents was involved productive age group (15-64 years old) based on data of Indonesian Statistics 2013. A productive age influences the ability of people both in physical and mind set as well as his ability in making a decision for technology adoption (Muis 2012 in Ref. 15). The education level of farmers was the especially primary school (40%) (Table 2). Ref. [16] stated that farmers with higher education are in general easier to adopt innovation and vice versa those with low education, generally rather difficult to adopt the innovation.

The average land area managed by farmers is 1.7 ha (Table 2), but the range varies from 0.25 ha to 9.5 ha. The status of the land mainly refers to the profit sharing system (65%). Usually, if the ownership of the farmer's property is less than 1 ha, some farmers then become sharecroppers on the land of other farmers in one village whose land is large enough with profit sharing system with a comparison of one part sharecropper and another part for landowner.

Table 2. General characteristics of farmers respondents in rainfed area of Tompobulu, Maros Regency, South Sulawesi, 2017

| General characteristics                     | Number (Percentage) |
|---------------------------------------------|---------------------|
| Age (year): (Average = 47,2)                |                     |
| 15-64                                       | 39 (97.5)           |
| > 65                                        | 1 (2.5)             |
| Education level:                            |                     |
| No school                                   | 13 (32.5)           |
| Elementary school                           | 16 (40.0)           |
| Junior high school                          | 8 (20.0)            |
| Senior high school                          | 2 (5.0)             |
| Diploma/ College                            | 1 (2.5)             |
| Number of family members (people): (Average = 5.6) |         |
| 1-4                                         | 10 (25.0)           |
| > 5                                         | 30 (75.0)           |
| Head of family’s main job:                  |                     |
| Farmer                                      | 38 (95.0)           |
| Stock farmer                                | 1 (2.5)             |
| Trader                                      | 1 (2.5)             |
3.2. Experience on soybean cultivation

Cultivating soybean is not a new thing for farmers in Tompobulu. They are cultivating soybean for about 20 years. However, soybean is not routinely grown every year by farmers because they depend on the availability of seeds and the desire of farmers to plant, so that farmers claim that the range of their soybean farming experience varies from 1 to 5 years or with the average is 3.4 years (Table 3).

Cropping patterns that are widely applied by farmers in rainfed area of Tompobulu are rice-secondary crop (soybean or corn or ground nut)-fallow. Rice planting time is in December or January with harvest time in late April or early May. The secondary crop planting period is from early May to August, then from August to November farmers leave the rainfed area fallow. The average land area cultivated by soybean is 1.4 ha (Table 3), but the range varies from 0.25 ha to 2.8 ha. Farmers usually apply monoculture planting type for their farming.

Table 3. Soybean farming experience of farmers respondents in rainfed area of Tompobulu, Maros Regency, South Sulawesi, 2017

| Soybean farming experience (year): (Average = 3.4) | Number (percentage) |
|--------------------------------------------------|---------------------|
| 1-5                                              | 38 (95.0)           |
| > 5                                              | 2 (5.0)             |

| Soybean planting area (ha): (Average = 1.4) | Number (percentage) |
|---------------------------------------------|---------------------|
| 0-1                                         | 18 (45.0)           |
| >1-2                                        | 13 (32.5)           |
| >2                                          | 9 (22.5)            |

Soybean seeds that are usually used by farmers is Anjasmoro variety. Anjasmoro is a variety that was officially released by Indonesian Agricultural Assessment and Research Institute (IAARD) in 2001 and is in great demand by farmers because it has the characteristics of plant that is able to adapt to very diverse agroecosystem conditions with high production, large seed, pods are not easily broken, crops are not easy to fall, and moderate to leaf rust disease [17,18]. However the purity of Anjasmoro seeds used by farmers is quite questionable because there are purple and white flowers. The seeds are taken from the previous year’s harvest that are stored in covered plastic jerry cans, are bought from other farmers or from collecting traders, as well as are received from government aid program A price of Anjasmoro seeds is IDR 7,000/kg, while for local varieties of soybean seeds are cheaper, ranging from...
IDR 3,000 to IDR 6,000/kg. The average seed used per ha is 53 kgs. Farmers never apply seed treatment before the seeds are planted.

Weeding is not a common thing done by farmers for soybean cultivation, although there are some farmers who claim they are still weeding up to 3 times in 1 planting season, namely before planting, at 2 weeks after planting, and 2 months after planting.

The processing activities carried out after harvesting soybeans are drying pods, threshing, sorting, and packaging in sacks. There are two methods of threshing, namely manual by beating and using thresher. The manual method is rarely done because the disadvantage of a high rate of yield loss. Threshing with thresher use rental system. For every 10 kg of yield, 1 kg is taken by the thresher owner as a rental fee.

Farmers’ harvests are usually bought by collecting trader in village. Collecting trader buys soybean from farmers at a price of IDR 6,000/kg (in 2017), then market it again at a price of IDR 7,000-8,000/kg according to buyer requirements. Marketing of soybean from farmers in the form of consumption seeds. The marketing flow of soybean in Tompobulu is quite simple, that is, after being bought by a collecting trader, soybean are routinely bought by tempe producers or buyers from Maros and Makasar or purchased as potential seeds by the private sector (but is not routine and depend on the private demand). Soybean received from each farmer, usually directly stored in the warehouse of the collecting trader. If the buyer wants soybean with lower moisture content, the collecting trader will dry the soybean again.

3.3. Financial analysis of soybean farming

Labor input cost accounts for the largest portion of the production costs of soybean farming, reaching 65% for “Biodetas” technology and 72% for existing one, and this is consistent with the research of [Ref. 19] and [Ref.20] . Labor input for soybean cultivation in Tompobulu usually only comes from labors in the family, except for planting and harvesting activities. Labor costs in the family are included as calculated input costs [20] (Table 4). Planting and harvesting activities require a large workforce so that in addition to being employed by labors in the family, they also pay for daily labor from outside the family. In 2017, daily wage of labor in Tompobulu was IDR 60,000/day.

The increase in the cost of production facilities of “Biodetas” was contributed by the use of organic Agrisoy (biofertilizer/seed treatment), organic Ze fertilizer, and leaf fertilizer, as well as the use of chemical for pest and disease control which amount to 2 times the treatment of farmer (Table 4). The use of fertilizer which is quite a lot both in terms of type and dose due to soybean planting area in rainfed area has irrigation characteristic which are actually very unfavorable for farming. So as to increase the yield, fertilizer doses that are adapted to the needs of plants during the growth period should be concerned.

The application of “Biodetas” technology can increase soybean productivity by 71% from 1.6 t/ha by existing method to 2.7 t/ha. This figure is higher than the potential yield of Anjasmor variety of 2.03-2.25 t/ha (Iletri 2016). With the selling price of soybean in the field in August 2017 of IDR 6,000/kg, the total revenue obtained by farmers with the application of the “Biodetas” technology package increased by 71% of the existing method. The profit of the Biodetas technology package also increased by 112% from the existing method (Table 4). The technology efficiency analysis shows that in addition to being efficient and profitable (R/C ratio> 1), “Biodetas” technology deserves to be further applied by farmers because by reducing the use of inorganic fertilizers and applying a combination of biofertilizer (Agrisoy), liquid fertilizers and organic fertilizers can further increase the productivity and profitability of soybean farming (B/C ratio> 1).

Radjit (1995) in [Ref. 21] stated that profit is an important factor in accelerating the adoption of technology in farming. Farmers generally will adopt a technology if the technology can improve yield, provide benefit, and be able to provide added value to limited resources.
Table 4. Financial analysis of soybean farming in two packages of biofertilizer technology for soybean “Biodetas” in rainfed area of Tompobulu, Maros Regency, South Sulawesi in the dry season of 2017 (May to August)

| Components                  | Soybean cultivation technology “Biodetas” | Existing (Farmers’ technology) |
|-----------------------------|------------------------------------------|--------------------------------|
| Production input costs (IDR/ha) |                                          |                                |
| a. Production facilities    | 2,593,000 (34.7)                         | 1,470,000 (27.5)               |
| b. Labor                    | 4,876,667 (65.3)                         | 3,880,000 (72.5)               |
| Total production costs (IDR/ha) | 7,469,667 (100.0)                       | 5,350,000 (100.0)              |
| Productivity (kg/ha)        | 2,725                                    | 1,590                          |
| Total revenue (IDR/ha)*     | 16,350,000                               | 9,540,000                      |
| R/C ratio                   | 2.2                                      | 1.8                            |
| B/C ratio                   | 1.2                                      | 0.8                            |

Notes:
The selling price of soybean in the location in August 2017 was IDR 6,000/kg
Figures in ( ) are percent of total production costs

3.4. Income of farmer’s households
Agriculture is a sector that contributes the highest income to farmer’s households in Tompobulu, which is 38.4% (Table 5). Rice still provides the highest income, while income from soybean has not been optimal yet because the average soybean productivity of farmer is only 1.0 t/ha with the selling price of soybean for consumption was IDR 3,000-4,000/kg in the previous harvest season. Stock farming sector provides the second highest income for farmer’s households with the range of cattle ownership in Tompobulu is 1-15 per household.

Table 5. Income of farmer’s households in rainfed area of Tompobulu, Maros Regency, South Sulawesi, 2017

| Source of income       | Average amount/year (IDR) | Percentage (%) |
|------------------------|---------------------------|----------------|
| Labor activities       | 7,925,000                 | 17.7           |
| Farm labor             | 852,500                   | 1.9            |
| Non-farm labor         | 7,072,500                 | 15.8           |
| Permanent work         | 5,125,000                 | 11.5           |
| Household enterprise   | 5,712,500                 | 12.8           |
| Farming sector         | 17,131,500                | 38.4           |
| Soybean                | 3,801,500*                | 8.5            |
| Rice and others        | 13,330,500                | 29.9           |
| Stock farming sector   | 8,772,500                 | 19.6           |
| Total (/household/year)| 44,666,500                | 100.0          |

Notes:
Percentage shows the comparison of each source of income with total income in a year
Income is calculated as the accumulation of income all family members of farmer’s household
*) The calculation comes from the previous harvest season with an average productivity of 1.0 t/ha, and the selling price of soybean for consumption was IDR 3,000-4,000/kg
Contribution of soybean farming to farmer’s households income can be calculated by comparing income from soybean farming with household’s total income (Milasari et al. 2015). There are five categories of contribution value, i.e. (1) very low (< 20%); (2) low (20-40%); (3) medium (41-60%); (4) high (61-80%); and (5) very high (> 80%). With the percentage of 8.5% (Table 5), the contribution of soybean farming to household’s total income was categorized as very low implied that farmer’s household can rely their income not only on soybean farming, but also on other farming sector (rice and stock farming), as well as on other sources of incomes as mentioned in Table 5 because their contributions.

3.5. Factors affecting farmers to adopt the biofertilizer technology of “Biodetas”

The result of regression analysis shows that determinant of technology adoption is the extent of soybean planting area (Table 6). X3 implies a larger soybean planting area will promote the adoption of technology. It may relates to the higher yield can be obtained by planting soybean on a wider area. It may be also related to land owners’ economic capability to provide the necessary production inputs in order to obtain the optimal yield. Non statistically significant of D1 suggests that the adoption of technology is not influenced by the land ownership status. For the land managed by profit sharing system, land owners still provide the inputs by sharing the production cost 1:1 with sharecroppers.

The negative sign of X1 implies that more years experience in soybean farming did not necessarily lead to the farmers’s interested to adopt “Biodetas” technology. X2 suggests that higher formal education does not affect the adoption of “Biodetas” technology. Farmers with higher formal education may be easier to accept new innovation, however it does not mean further they will always be interested in adopting the technology.

X4 implies that the higher soybean production cannot affect farmers to adopt technology. It may be caused by the very low contribution of soybean farming income to farmer’s household total income if compared to other sources of income (Table 5). Therefore, non statistically significant of D2, D3, and D4 implies that biofertilizer and improved soybean varieties access as well as the higher production cost should be provided by farmers due to the application of “Biodetas” technology components are not considered by farmers to adopt technology as long as the income they earn from soybean farming is still much lower than the other sources. In this case, it seems that the policy of the higher soybean selling price in farmers level may be more attractive to farmers to adopt technology introduced by Iletri which actually have been able to increase the productivity of soybean.

| No | Variables | Coefficients |
|----|-----------|--------------|
| 1  | X1        | -0.500       |
| 2  | X2        | -0.023       |
| 3  | X3        | 6.969*       |
| 4  | X4        | -0.004       |
| 5  | X5        | 0.000        |
| 6  | D1        | 0.021        |
| 7  | D2        | 0.628        |
| 8  | D3        | 0.800        |
| 9  | D4        | 0.350        |
| 10 | α (constant) | -3.880    |

Notes:
Level of confidence: * =95%
Variables: (1) X1= farmers’ experience on soybean cultivation, (2) X2= formal education, (3) X3= the extent of soybean planting area, (4) X4= soybean production, (5) X5= income from soybean, rice, and other farming activities, as well as dummy variables for (1) D1= land ownership status, D2= consideration on biofertilizer production input access, D3= consideration on improved seed access, and D4= consideration on higher production cost should be provided by farmers.
4. Conclusion

The application of “Biodetas” emphasizes the use of biofertilizer, leaf/liquid fertilizer, and organic fertilizer with a reduction in the dosage of inorganic fertilizers was able to increase soybean yield higher than the existing technology and it is economically feasible to be adopted by farmers. However, the higher soybean production cannot affect farmers to adopt technology. It may be caused by the very low contribution of soybean farming income to farmer’s household total income. Determinant factor of technology adoption by farmers was the extent of soybean planting area. The larger of soybean planting area will accelerate the adoption of technology. It may relates to the higher yield can be obtained by planting soybean on a wider area and also related to land owners’ economic capability to provide the necessary production inputs in order to obtain the optimal yield. The policy of the higher soybean selling price in farmers level may be more attractive to farmers to adopt technology introduced by Iletri which actually have been able to increase the productivity of soybean.

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