SCIENTIFIC EXPLANATION REPORT EX POST

Title of the project: **Method of restoring vegetables from parasites by microwave (RISALE)**

Coordinator: **Prof. Pio Federico Roversi**, CRA-ABP Research Center for Agrobiology and Pedology, via Lanciala, 12 / A, 50155 Florence

Project launch date: approved it **05/12/2006**

Project Completion Date: 31/03/2010 (report received by Coordinator i14 / 02/2011)

A) Facts about the activities actually carried out

The study carried out in the RISALE project involved the development of new technologies for the physical disinfestation of leguminous seeds intended for human consumption during storage and storage. Technological innovation in the use of a static experimental system for reverberating rooms, under conditions of optimization of results, and for the development of a continuous plant equipped with microwave emitters. These different technologies based on the same principles have been compared with fast matrix cooling treatment and as an alternative to the use of chemical treatment.
The research was carried out in collaboration with three operating units:
U01 CRA-ABP - Research Center for Agrobiology and Pedology in Florence (coordinator and unit involved in the breeding of Brucsides and in the determination of disinfectant efficacy) ,
UO2 CRA-IAA - Research Unit for the processes of the agro-food industry in Milan (unit involved in the qualitative determination of food matrices and cold treatment),
UO3 -la EMitech srl (Electro Magnetic Innovative Technologies) company in the province of Bari (unit involved in the design, realization and optimization of microwave plants).

B) Excerpts from possible project deviations

The overall objectives of the project, which consisted in the development of advanced and economically viable technologies of physical disinfestation of the main leguminous seeds, have been achieved. Microwave treatment, through the production of a continuous process equipment, achieves both the industrial purpose application of high quality and germinability of the product and the economic one, alternating with conventional chemical treatments. Even cold treatment has given good results, but with slower treatment conditions. Therefore there are no discernible deviations from the objectives indicated in the project by those pursued by the activity carried out.

C) Outline of the achieved results

The scientific activity of the CRA-ABP was in perfect alignment with the other Units (C.R.A.-IAA and EMitech, responsible for the realization of the microwave prototype). In fact, the complexity of the actions planned and realized in the project, together with the indispensable interaction between the united operating units, had to be based on a perfect partnership of the parties.
The scientific investigation has demonstrated the treatment with the legume microwaves, for the purpose of insect pest control, has not changed the general quality framework of the seeds themselves.

The results obtained with it being much longer and a little less effective than the one with the microwaves, showed results that indicate better microwave adoption.
Irradiation tests at fair speeds of transport velocity, with different electromagnetic energies, with controlled temperatures and with the evaluation of homogeneity of treatment, gave the following

results: results obtained for adult insects by verifying 1 hour And 24 hours of treatment while for preamaginal stages (eggs and larvae) it treated the material and was placed in a breeding chamber at 25 ° C until the adult stage of the Bruchidi showed that from 2.15 to 2.30 Min with 1 kW of radiant power, almost the totality of elimination of adults, larvae and eggs of A. obtectus and C. maculatus.

Only with it seed of the bean (was operated with a particularly large seed variety) there were problems: hopper opening did not guarantee the flow of the seed that stuck, resulting in overheating of the material and interruption of the test. On completion of the investigations, germinability tests were carried out for chickpeas, cicerola, lentils, beans, and beans treated with 1Kw microwaves and with exposure times of 1'30 ". With the exception of the seeds of beans, Not germinate, and it was evident that the normal germination of the seeds tested (subjected to micro-treatments), compared to untreated seeds.
The scientific contents of the turnaround are of good value and are more than compatible with a high acceptable level of tolerance.

D) Evaluation of the Real Value of Results and Possible Reactions

The results obtained are of good application value and represent a breakthrough in the principles used for the purpose of disinfection of food materials and, in this case, of seed applications. The foreseeable consequences concern post harvest and seed sectors, with main applications for the storage of raw materials with no toxins, with economic implications for the further storage and recovery of at least 10-15% of the product. The commercial sector of leguminous crops and grain harvested by physical treatment (microwave and cold) as an alternative to the chemical, which is still unhelpful in all sectors of the agri-food industry, will resonate both at national level and International level. In addition, the lower negative impact on the environment, which should be expected, will have repercussions on consumer health currently difficult to quantify, albeit absolutely safe and real.
of)

E) Assessment of the actual impact on the scientific, productive and social system

Microwave technology, with respect to the most disused seed pests, has qualitative advantages as well as positive interaction with the environment compared with those related to negative impacts environmental. Therefore, the foreseeable impact will be on reducing the losses of legumes during storage, the elimination of possible levels of pollution related to conventional chemical treatments and the availability of better legumes for both hedonistic and consumer health.

The need for the production of innovative equipment for it's microwave treatment develops an increase in technicians and plant conductors. In addition, the future availability of these plants will lead to their application in sectors of other agro-foodstuffs and perhaps even distant from the agri-food sector.

F) Assessment of the prospective activity, of the results achieved in relation to the needs of the sub-sector

The results achieved in the treatments under optimized conditions in the project provide for an activity of plant development and dissemination of their use in the agri-food sector for purposes Of rehabilitation. Therefore, it is easy to imagine the range of advantages for this product, in terms of the quality of the result both for the seed and for the cleansing and treating of the treatment, in addition to the substantial reduction in the loss of conservation. Moreover, it can be seen that development can also be directed towards further innovation and applied in other application areas, although not yet well-identified.

G) Total final assessment

Objective 1, 2

The research was carried out on seeds of various legumes on which microwave and cold-cooling tests were conducted, the development and use of evaluation methods of effects Chemical, physical and sensory, also on the corresponding cooked products, to establish the maximum limits of treatment in relation to the degradation of legume quality. The objective has been achieved, at costs that are compatible with the activity, with the possible impacts associated with the achievement of targets 5 and 3.4.

Objective 3, 4

The research carried out included the finding of the main species of beetle beetle weeding the legumes and the production of greenhouse and air conditioned cellar farms on some reference legumes. A series of tests were carried out to evaluate infestation levels in relation to different conditions and exposure tests (temperature-controlled power-time) were conducted in static reactive radiative room and in the prototype plant for continuous treatment of legumes at Microwave (CRA - ABP). The objective has been effectively achieved by using it appropriately funded. The impacts are closely related to the results of Objective 5 and, therefore, of possible industrial interest, verified from the economic point of view at the end of the project activity.

Objective 5

The research carried out has produced a reverberating room prototype, equipped with a stirring system, which has been tested on real legume systems. The work continued with the design of a plant characterized by legumes transported continuously under the radiant source, as a substantial modification of the "static" plant. In addition, this modification prevents separation from the insect system with the wings, at the earliest heat development. This change has provided optimum treatment results. The goal is to be considered more than achieved, the expected costs and possible industrial implications of industrial application, also evaluated for the economic aspects, at the end of project activity.

Initiatives for presenting the project

Over the last two years, several presentations have been presented at National Conferences through communications and several papers have been published in magazines. His entrepreneurial business contacts, particularly with seed companies, have shown a great interest in possible applications of microwave technology.

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Detailed report

Objective of research in the project

Study of a new high-tech technology capable of maintaining and promoting a high qualitative standard of legumes in relation to the elimination of possible pest infestation in various stages of development. The aim of this innovation and the agri-food business provides for the stabilization of legumes production, associated with high food security.

Summary of the activity

The study conducted in the RISALE project involved the development of new technologies for the physical disinfestation of leguminous seeds intended for human consumption during storage and storage. Technological innovation in the use of a static experimental system for reverberating rooms, under conditions of optimization of results, and for the development of a continuous plant equipped with microwave emitters. These different technologies based on the same principles have been compared with fast matrix cooling treatment and as an alternative to the use of chemical treatment.
The research was carried out in collaboration with three operating units: U01 CRA-ABP - Research Center for Agrobiology and Pedology in Florence (co-ordinator and unit involved in the breeding of the Bruchidi and in determining the disinfesting efficacy) , UO2 CRA-IAA - Research Unit for the processes of the agro-food industry in Milan (unit involved in the qualitative determination of food matrices and cold treatment), UO3 -la EMitech srl (Electro Magnetic Innovative Technologies) company in the province of Bari (unit involved in the design, realization and optimization of microwave plants).

Turning activity

Initially, tests were carried out with a "model" microwave outfit, a prototype of reverberating room to static microwaves, then gradually modifying it to make the results optimal and construct a prototype with continuous handling of legumes to be treated up To the construction of a continuous, fully automated microwave plant, suitable for industrial applications.
Initial tests were focused on identifying the minimum conditions until homogeneous treatment conditions were obtained for calibrated times to obtain the best possible correspondence of the characteristics of the tested matrices possessed for it product

Untreated, obtaining the high silicon elimination possible of insects and larvae specially embedded in legumes.
The evaluation of the results was obtained through physical chemical analysis, conducted both on untreated legume samples on the corresponding treated, with and without rehydration, with and without cooking. The parameters identified for comparisons between different technological processes were the conformation and the integrity of the pulses, it their color, the concentration of soluble solids in the water of rehydration and cooking, the assessment of turbidity of water and rehydration Baking, evaluation of the hardness of the tegument of rehydrated and cooked vegetables and, in a second phase, its starch content (by HPLC).
The measure of effectiveness disinfestante and was conducted on artificially infested legumes with Bruchidi Acanthoscelides obctectus (Say) and Callosobruchus maculatus (F.) at different stages of development, assessing the percentage of mortality of the same at the end of the disinfestation treatment by the microwaves .
In order to complete the investigations, germinability tests were carried out for chickpea, cicerchia, lentil, bean and bean seeds treated with microwaves.
In parallel with the study of the activity of the microwave, the employment Possibility was also depth of rapid cooling techniques for control of pests parasitic en seeds, for which the effective time on the measured disinfestation, are decidedly more long results compared to those Obtainable with microwaves.

Specific Objectives

(1) Determination of minimum and effective limiting conditions for treatment in reverberating rooms for fresh and dried legume microwaves of the main cultivated species in Italy (CRA-IAA).
(2) Identical study of the effects of fast-cooling technology with forced air (CRA-IAA).
(3) Identification, within the usable ranges without damage to the seeds of leguminous plants, the treatment conditions (powers to use and timing of treatment) in reverberant rooms to microwaves to obtain complete disinfestation Legume from eggs, the juvenile forms And adults of the main arthropods included among the indigenous and exotic Bruchid Coleotteri capable of infesting fresh and / or dried legumes (CRA-ABP).
(4) An identical study of the effects of CBS-ABP rapid-cooling technology.
(5) Realization of a prototype of disinfestation equipment based on the technology of microwave reverberation rooms, equipped with a conveyor belt and an electromagnetic power distribution optimization system, which enables it to be able to be refurbished quickly and without risk to the operators (EMitech srl).
(6) Construction of specific operational protocols for disinfection of the vegetables with the two technologies, the effectiveness of cross-check and the costs of the compared systems (CRA-ABP; CRAIAA; Emitech Ltd.).

Objective 1, 2
-Evaluation of the effects of microwaves, and those of the rapid cooling, through the quality parameters of seeds of white kidney beans, pinto beans and chickpeas (CRA - IAA). - Legumes: Cinnamon beans, Borlotti beans and chickpeas, processed and untreated with microwave, with subsequent heat treatment (CRA - ABP) have been studied.

- Evaluation of the quality of processed, unmanaged and unbroken legumes, after rehydration, baking behavior through proper organoleptic, rheological and chemical-physical measurements (CRA-IAA).

Objective 3, 4
Collection and breeding of beetles Pests of beet pulp, their controlled insertion into the legumes studied, evaluation of the level of infestation carried out and preparation of microbial treatment tests in static equipment (CRA – ABP).

Objective 5
Following the preliminary testing of static reverberation, a prototype of a continuous disinfestation system, based on the technology of the microwave reverb room (EMITECH srl), was established. Treatment conditions were developed both under static conditions (reverberating form) and on the continuous experimental plant, with the treatment of winged insects tending to move away from the treatment area (container of continuous transport enclosed In cylinder) (EMITECH srl).

Activities of individual Uos

Objectives I, 2 (CRA-IAA)
The activities envisaged and carried out by the CRA-IIA Operational Unit have been related to:
- collaboration on the design of the pilot plant for microwave treatment, for dynamic static devices For the methodologies of acquisition and recording of data;
- the setting up of protocols required the adoption of refrigeration techniques, both for cold storage treatments and for quick seed cut-out after microwave exposure;
- qualitative surveys on seeds treated with microwaves to ascertain any changes in physical, chemical, sensory characteristics.

The distribution of temperatures in the leguminous microorganisms in the static system, in order to homogenize them in the mass, was achieved by the production of a continuous mechanical stirrer. In addition to the study of the effects of microwave treatment, in the static and continuous conditions 6, the possibility of the use of refrigeration techniques for it control of weeds parasite control (CRA-IAA) has been considered. In this treatment system, the effectiveness of disinfestation has been linked to several variables:
1) genus and species of the insomofauna to be controlled and its physiological stage
2) host substrate and its systematic position (genus, species, variety) and state of Storage: (dry substance, residual humidity, SI / NO packaging mode, pre-stored storage conditions)
3) Time / temperature binomial exposure to cold action
4) Cooling cycle trend (temperature fluctuations, ventilation, Door openings).
5) Possibility of secondary infestation (downstream).

Objective 3.4 (CRA-ABP)
The Co-ordinating Unit (CRA-ABP) carried out the infested legume samples in a controlled manner and verified their level of infestation, which, after treatment with microwave (CRA-

sIAA and CRA-ABP) or with the action of cold (CRA-IAA) returned to the CRA-ABP for the assessment of mortality induced by the various treatments. For the evaluation of the effects of van treating on the legumes studied, the parameters considered were:
Legumes such as:
- image acquisition of dried pulses
- visual inspection of dried legumes

- color of the epidermis of dried legumes.

Legumes after rehydration

- image acquisition rehydrated legumes
- visual comparison of legumes after rehydration
- color of rehydrated vegetables epidermis
- evaluation of the concentration of soluble solids in rehydration water
- evaluation of the rehydration water turbidity
- analysis of the hardness of the tegument Of rehydrated vegetables.

Legumes after cooking

- capturing images of cooked legumes
- visual comparison of legumes after cooking
- color of the epidermis of cooked legumes
- evaluation of the concentration of soluble solids in the cooking water
- evaluation of the cooking water turbidity
- analysis of the hardness of the tegument Of cooked legumes.

On treated and untreated legume samples, after rehydration and after firing, starch was evaluated by enzymatic and chromatographic quantification (HPLC) with glucose-derived degradation analysis.
In addition, germinability was not compared with the treated samples.
After the CRA-ABP UO, as envisaged in the project, completed studies concerning the radiant reactive radiant microwave chamber, resulting in a uneven distribution of radiant energy, carried out investigations into the effectiveness check against Of poultry bred the legumes of a prototype of dynamic radiative equipment. The results of these surveys have led to the design and construction of the U.O. EMITECH srl, of a reverberating "continuous" room. It is characterized by a system of transport and optimization of the distribution of electromagnetic power which can be considered the prototype of departure for: industrial scale application of microwaves for the protection of legumes. In order to carry out all the experimental tests for the new prototype, a 10 month extension at the expiration of the project was requested, moving its deadline to October 31, 2009.
During the waiting period of the new prototype, in collaboration with the IAA of Milan and U.O. EMITECH srl, en CRA-ABP has conducted treatment trials with the cold under conditions;
Species: Acanthoscelides obtectus and Callosobruchus maculatus
Development stage: adult and eggs / larvae
Type of legume: cannellino bean and bean with the eye Repetitions for thesis: 4 for adults, 6 for eggs / larvae Display times: 18, 24, 30 hours.
The test variable 6 was it temperature level:
-Repeat 1 - Test temperature -7 ° C
-Repeat 2 - Test temperature -13 ° C
-Repeat 3 - Test temperature -10 ° C

Different tests on different radiant energy (magnetron power) and continuous conveying speed of the conveyor were performed on the new equipment. The results obtained showed a good efficiency of the equipment, but in 2009 it was shown that the two species of breeding Bruchids had developmental capacity to grow besides beans, also other legumes (bean, cicerchia and Lentils) provided for in the project.
Irradiation tests were carried out at fair speeds of transport, at different electromagnetic energies, by measuring the obtained temperatures and evaluating the homogeneity of the treatment. The germination of treated and untreated seeds was also evaluated.

Objective 5 (EMITECH srl of Molfetta)

The activity carried out at MOLFETTA EMITECH srl has been focused on the development of processing conditions with microwaves of legumes, modification of the static system and the development of the prototype Of the dynamic plant with closed and transparent tubular conveyor to the microwave after some modifications.

These modifications have provided for:

- replacement of the transport conveyor module with a helical conveyor;
- the creation of loading and unloading modules suitable for the passage of legumes, which form an electromagnetic filter for the microwaves and integrate with it a new transport system;
- shielding for new use;
- the creation of sensors suitable for monitoring the status of the product. Also on this latter plant, irradiation tests were carried out at fair speeds of transport, at different electromagnetic energies, by measuring the obtained temperatures and evaluating the homogeneity of the treatment.

On different legumes (chickpeas, bean sprouts and cannellini beans) to electromagnetic energy it was desired to carry the seeds at temperatures well above those lethal for insect infestations (57-60 ° C). Tests that have reached temperatures of 60 to 15. T 75 ° C showed no detectable damage (seeds breaks, color changes).

The final disinfestation plant consists of:

- a screened tunnel, ie a Faraday cage designed and verified at the operating frequency of 2.45GHz made by assembling bolted metal elements. Inside, an electromagnetic field is generated and completely enclosed at the microwave frequency and with a minimum power of 12 kW;
- within the tunnel a circular section (15 mm thick, 60 mm diameter) dielectric (Polypropylene) plastic tube has been installed in which the pulps to be disinfected are transported by means of a transport module Helical type;
- a conveyor system consisting of a metal helix that, rotated by a three-phase STM VEL engine and an STM gearmotor, rotates inside the microwave tube; -the rotation speed of the electric motor can be varied by means of an inverter, thus modifying the amount of material transported. The increase in the number of gins per minute of helixide results in a reduction in the time of exposure of the seeds to the microwaves and an increase in the plant's flow rate;
- loading and unloading systems placed at the beginning and end of the shield tunnel allow the inlet and outlet of the matrix to be subjected to microwave treatment.

Treatment times were short: a few minutes (2.5 minutes).

Another objective of the research was to verify the applicability of a microwave device for the disinfestation of legumes within an industrial plant (capacity of at least 1000 kg / h). In the test condition, the power of the microwave at 36 kW and the microwave exposure time of the matrix is set so that it can work at maximum productivity compatible with the disinfestation temperatures. Using it pea seed for testing, it is best achieved by reducing the speed (inverter) and state of 1/15.

Using its industrial prototype with an hourly flow rate of 1000 kg / h, macroscopic effects on seed quality such as breakage, color change, presence of any combustible parts were evaluated by controlling the superficial temperature of the matrix subjected to microwave treatment A Thermacam SC2000 type infrared thermocamera, recognizing a homogeneous transport and heating.

RESULTS

The scientific activity of the CRA-ABP coordinated unit has been in tune with the other Units (C.R.A.-IAA and EMitech, responsible for the implementation of the microwave prototype). In fact, the complexity of the actions planned and realized in the project, together with the indispensable interaction between the united operating units, had to be based on a perfect partnership of the parties.

Based on the analytical evaluations used for comparison between treated and untreated pulses, for the different treatments, from a purely qualitative point of view, the scientific investigation has shown that it is treated with microwaves of leguminous vegetables for insect pest control Did not change the general quality framework of the seeds themselves. The results obtained with it were definitely pin long and slightly less effective than the one with the microwave, showed results indicating better microwave adoption.

In the context of the activities that may seem worthy of consideration, but it has not been possible to set aside for problems of time and availability of funds:
1. Cooling of seeds treated with solid carbon dioxide pellets, added to the seed mass outflow From the microwave area. By mixing the seeds with the addition of adequate quantities, pellets can contribute to the rapid reduction in seed temperature with possible qualitative improvement of the treated product.
2. Use of flowing steam, sprinkled on seeds through it passage of mass on a variable speed conveyor belt. This is a pilot plant used by Unit C.R.A.-IAA for burning vegetables before blanching. The pilot tunnel consists of two heating sections with nozzles that dispense flowing steam and one cooling with nozzles distributing network water. The working hypothesis could have contemplated that the first heating section would follow a cooling by compressed air jets emitted by the same water nozzles.

Forced ventilation could have corrected the possible rise in temperature produced by the steam. Irradiation tests at fair speeds of transport, with different electromagnetic energies, with controlled temperatures and with the evaluation of homogenous treatment, gave the following results:
-results obtained for adult insects by verifying 1 hour And 24 hours of treatment while for preamaginal stages (eggs and larvae) it treated the material and was placed in a breeding chamber at 25 ° C until reaching the adult stage of the Bruchides, showed that

From 2.15 to 2.30 min with 1 kW of radiant power, almost the total elimination of adults, larvae and eggs of A. *obtectus* and C. *maculatus*.

Only with it seed of wood (was operated with a particularly large seed variety) there were problems: the opening of the hopper did not guarantee it flow of the seed that was stuck causing a material overheating and the interruption of the test. On completion of the investigations the germinability tests for chickpeas, cicerola, lentils, beans and beans treated with microwaves with powers of 1Kw and with exposure times of 1'30 ". With the exception of seed crops, which can not be germinated, And the normal germination of the seeds tested (subjected to treatments with microwaves) was evident compared to untreated seeds.

Conclusions

The activities provided for in the project were carried out in full collaboration between the UOs involved. The results are of great use for the sanitisation of leguminous seeds.
From the analysis of the analysis, it has emerged that it may have detectable effects through the microwave-reset treatment through the parameters considered, but which, however, have no appreciable reflections on the qualitative, merchandise and sensory characteristics of the products.
Testing of rapid-cooled temperature tests (-7 to -10 and -13 ° C) showed that both of the tested Bruchide species were sensitive to low temperatures, but the exposure times were very high Longer than those required by microwave treatments to achieve comparable results in disinfestation.

In comparing the total cost of the treatment, ignoring the indirect environmental costs associated with treatments with other possible (conventional) solutions, the cost of the gas was considered (18 E / Kg for CH_3Br and 31 € / Kg for PH_3). Gas consumption per tonne (187 g / t for CH_3Br, 11.2 g / t for PH_3 + 30 kg / t CO_2), cost of labor (25 € / h considering a commitment of 0.37 hit For CH_3Br, 0.5 h / t for PH_3 and 0.08 h / t for Microwaves), the cost of electricity (considering energy cost of 0.15 € / kWh and consumption of 1.5 KWh for CH_3Br, 2.5 kWh / t for PH_3 and 48 kWh / t for Microwaves).
In addition, by analyzing the data, it emerges that it is economically viable with the automatic management of microwave operation; It is a beneficial microwave process both for the disinfection with methyl bromide (gas being banned) and for the disinfestation with phosphine.

All of the results are from a scientific viewpoint of great features. All results are compatible with more than just acceptable search activity.

Final overall assessment, in terms of the effectiveness of the intervention, on the basis of the costs incurred and the foreseeable overall impact

Objective 1, 2

Research was conducted on seeds of various legumes on which tests of microwave treatments were conducted Rapid cooling, the development and use of methods of assessing the chemical, physical and sensory effects on the corresponding cooked products, in order to establish the maximum limits of treatment in relation to the degradation of legume. The objective has been achieved, at costs that are compatible with the activity, with the possible impacts associated with the achievement of targets 5 and 3.4.

Objective 3, 4

The research carried out included the finding of the main species of beetle beetle weeding the legumes and the realization of greenhouse and air conditioned cellar farms on some reference legumes. A series of tests were carried out to evaluate infestation levels in relation to different conditions and exposure tests (temperature-controlled power-time) were conducted in static reactive radiative room and in the prototype plant for continuous treatment of legumes at Microwaves (CRAs - ABP). The objective has been effectively achieved by using it appropriately funded. The impacts are closely related to the results of Objective 5 and, therefore, of possible industrial interest, verified from the economic point of view at the end of the project activity.

Objective 5

The research carried out has produced a reverberating room prototype, equipped with a stirring system, which has been tested on real legume systems. The work continued with the design of a plant characterized by treatment of legumes transported continuously under the radiant source, as a substantial modification of the "static" system. In addition, this change prevents the insects from being separated by wings from the system, to the early heat build-ups. This change has provided optimum treatment results. The goal is to be considered more than achieved, the expected costs and possible industrial implications of industrial application, also evaluated for the economic aspects, at the end of project activity.

Initiatives for presenting the project

Over the last two years, several presentations have been presented at National Conferences through communications and several papers have been published in magazines. His entrepreneurial business contacts, particularly with the seed company, showed great interest in possible applications of microwave technology.

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