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The Vitamin E Expansion Project (VITEX)

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Abstract: Following an extensive internal site evaluation process, in 2000 Hoffmann-La Roche (the former Roche Vitamins Division belongs today to DSM through an acquisition in October 2003 as DSM Nutritional Products) made the decision to build the world's largest Vitamin E plant in Switzerland. This article describes the necessity for this major investment, the decision-making process, the course of the project, and its outcome. In conclusion the decision is challenged in the light of today's general conditions.

Keywords: Industrial synthesis · Process technology · Site evaluation · Tocopherol · Vitamin E

History

Vitamin E was first discovered by Evans and Bishop in 1922 [1]. A deficiency of what was then called 'food factor X' was noted to cause foetal death in laboratory rats. Later this substance was named vitamin E and then given the name tocopherol. The isolation of vitamin E followed by Evans in 1936 [2] and the elucidation of the chemical structure by Fernholz in 1938 [3]. Karrer, a professor of Zürich University succeeded in synthesizing the first DL-α-tocopherol molecule from 2,3,5-trimethylhydroquinone and phytyl bromide in the same year [4].

This was the starting point for the first industrial synthesis of racemic DL-α-tocopheryl acetate by Dr. Otto Isler, a Roche employee, who succeeded in transferring the lab synthesis into a technical process in Basel [5], producing a couple of hundred kilos per year. In the following decades the process was continuously optimized. A technical and commercial breakthrough was achieved in the beginning of the seventies by installing vitamin E plants in Sisseln (AG), Switzerland and in Nutley (NJ), USA with capacities of several thousand tons per year.

Growing Market

Over the years more and more studies showed health benefits for humans and animals by intake of vitamin E in doses which could not be achieved with normal nutrition. Reduction of coronary heart disorders, improvement of liver functions as well as benefits for skin and hair and the well-being of animals, to name only a few examples, were proven by scientific studies [6]. The result was a steadily growing market with food/pharma and feed sectors with a yearly growth of 3–5%. In the 1990s Roche Vitamins Division was still the world market leader for vitamin E products with a market share of approx. 40%.

In the meantime several developments have taken place which called for a new strategy in the vitamin E business.

First of all it could easily be calculated that with continued market growth Roche's maximum vitamin E production capacity would be reached in 2004 and, in spite of the ongoing de-bottlenecking processes, could not be increased significantly. Upgrading and enlargement of the existing plants were not an option either, because of time-worn equipment after almost 30 years of service and increasing maintenance costs. In addition, Roche USA had made the strategic decision to close down its entire chemical bulk production in Nutley as part of its conversion to a purely pharma site.

At the same time, increasing competition from upcoming Chinese producers and the Vitamin Antitrust Case put the vitamin E business of the western world under substantial pressure. Therefore the need to upgrade Roche's vitamin E production technology became critical to regain cost leadership – and in the long run, it became a matter of survival in the vitamin E business.

This all resulted in a decision to expand the vitamin E production to a capacity of 25,000 MT per year with the newest technology available.

Site Evaluation

At the beginning of the site evaluation process a two-site scenario was discussed over an extended period of time. The idea was to maintain the old plant in Sisseln, Switzerland and to build a new one in Freeport, Texas. At that time a smaller vitamin E plant in China was already on line, built within a joint venture with a Chinese producer. However, to expand this plant was not an option at that time for strategic reasons. Instead, calculations were made to expand the Sisseln plant by doubling its capacity. This scenario attracted a lot of attention, since capital investment was much lower than in all other scenarios previously calculated. This was the result of Sisseln's existing infrastructure which was capable of supporting the expanded vitamin E plant with only minor investment as well as the application of new technologies. These new technologies would have a substantial effect on capital investment – setting a benchmark for all following scenarios. However, it was obvious that the effect of new technologies could be applied to other discussed scenarios as well, independent of location. The evaluation finally ended up with a comparison of the Sisseln one-site scenario with another setting, to keep the

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Sisseln plant and to build a medium-sized plant in China.

Surprisingly, using the most advanced technology in both scenarios, the financial analysis did not allow a clear distinction between the two cases. Another argument which finally turned the balance was the requirement of possessing a 100% ownership when advanced technology is transferred to China. Due to time constraints for negotiations with the joint venture partner this option was finally abandoned. The speed of implementation was critical in order to achieve the ambitious economic goals.

In November 2000, the vitamin E expansion project called VITEX with a budget of 179 Mio Swiss Francs was approved by Roche's executive committee, to be implemented within three years in Sisseln, Switzerland.

Process Technology

The chemical process used for the VITEX project is still similar to Karrer's synthesis, developed over 60 years ago. The heart of the synthesis is the condensation reaction of 2,3,5-trimethylhydroquinone (TMHQ) with in-house manufactured isophytol to form the vitamin E molecule DL-α-tocopherol l (Scheme 1).

Trimethylhydroquinone is produced in a two-step process by oxidation of 2,3,6-trimethylphenol, an intermediate commercially available from the oil industry, followed by hydrogenation of the derived 2,3,5-trimethylquinone (Scheme 2).

The crude tocopherol is worked up and purified by high-vacuum distillation. The main part of this material goes through an acetylation process to form DL-α-tocopheryl acetate, which is stable to air. Feed grade and pharma grade are the two qualities which are sold as bulk material or transferred to in-house formulation processes.

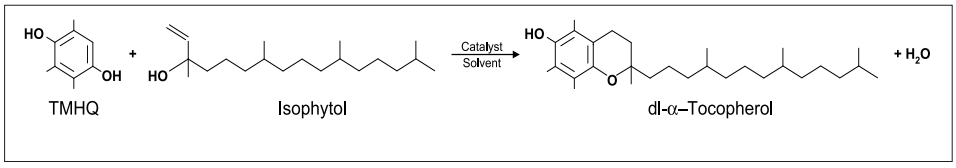
Readers might ask what was really new; what kind of advanced technologies were applied in the VITEX project? In Isler's days the challenge was to transfer a lab synthesis into a technical process as closely as possible. Since equipment and methods used for these unit operations in the laboratory could be applied to a variety of processes, cost efficiency was not an issue. As a result, the first generation process technology used the same methods and unit operations as in the laboratory and was therefore not the most cost efficient. Thirty years ago, with good margins on the product and minor competition, cost leadership was not as important. However, in recent years, as outlined above, this issue becomes dominant.

The challenge to create a modern highly efficient technical process cut these edges and detours and converted the synthesis into a lean, highly automated and dedicated plant.

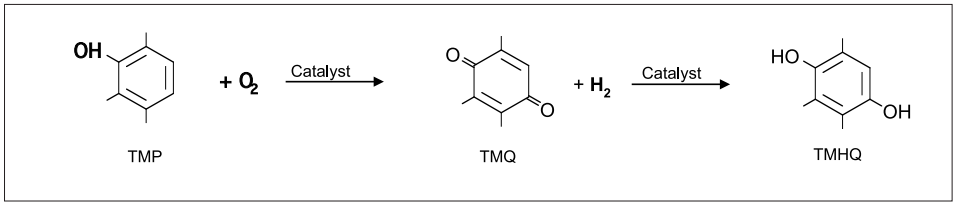
One example of innovation was the application of new thermal separation techniques together with a better concept for managing recycling streams, approaching higher yields. This also meant applying high automation standards which set the basis for a drastic headcount reduction while fostering constant output and quality. This was also supported by the utilization of inline analytic methods which helped to monitor the process at the most early stage.

Besides process technology, high safety standards were applied, firstly to ensure safe working conditions, but secondly also to minimize the risk of a process interruption, which is an important factor in a single-site production set-up.

To be ahead of future regulatory requirements, high environmental standards were implemented by minimizing liquid and solid waste as well as waste water and air pollution. As implemented over a decade ago in Sisseln, off gases and liquid wastes are incinerated on-site in the boiler house.



Scheme 1



Scheme 2

Worth mentioning is also the adoption of a high energy efficiency process which is becoming more and more important with increasing energy costs.

The result was a tailor-made, highly cost efficient plant, designed to achieve cost leadership in the hard-fought vitamin E market.

Course of the Project

As outlined above, the time factor was critical to reach the economic goals. Shortly after approval, a team was put together to push the project forward at maximum speed. All functions of engineering, chemistry, R&D, automation as well as representatives from the old plant operations worked together in a core team, which was responsible for all design phases and the execution of the project. Contractor management was handled by technicians especially skilled in installation.

At the foundation ceremony in August 2001 Roche's managing director underlined the high importance of the project for the Vitamins Division and emphasized in his speech that having highly skilled and motivated employees in Switzerland had been an important factor for project approval.

In the following months the project moved along to reach its important milestones. In April 2002 the manufacturing building and the adjacent tank farm were ready for equipment installation. One year later the upper steps (work up & purification) were set up for starting the commissioning process. This was possible because the old plant was able to deliver crude tocopherol to the VITEX process. The successful start up allowed the Nutley facility to be shut down in November 2003. Half a year later the lower steps along with all the critical chemical processes began their start-up procedure. In June 2004, almost six months ahead of plan, the old vitamin E facility in Sisseln was shut down and the project was closed. The budget could be kept under control (Fig.).

Success Factors

In the project's aftermath it is worth looking at the various factors which are believed to have helped to make the project a success.

Piloting for all critical process steps was performed in the nearby development department. Where outside expertise was required, some piloting work was also done externally in close cooperation with the suppliers. In this front end loading process most of the piloting work was completed before the basic design phase started. In this way corrective measures could be im-

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Fig. The new vitamin E production facility in Sisseln, Canton Aargau (Switzerland)

plemented with only minor impact on the budget.

Process engineering was performed in-house by a corporate function. Therefore contractor business was limited to more or less execution only. It turned out that this sharing of responsibilities was especially beneficial for processes which were not 100% defined and clear at the start of the project.

The staff of the nearby old vitamin E plant provided the project team with 30 years of know-how and delivered representative substances for extensive material testing. Important for the implementation of the start up concept was the ability of the old plant to deliver intermediates *to*, and, at the same time, to process products *from* the new process.

The project organization was set up in the form of three parallel working teams with high skilled and motivated people for the lower steps (chemistry), upper steps (work up & purification) and infrastructure with clear targets, clear responsibilities and decision-making competence. As another important success factor these crossfunctional teams did not change a lot between piloting and start up.

At different phases a project risk analysis was performed by a group of in-house experts to identify problems at an early stage which enabled the team to take corrective measures in time.

Conclusion

At the end of this success story, having reached the project's milestones in terms of time and budget, and having reached operational goals of quality and manufacturing cost, it seems to be almost heretical to raise the question of why the investment was not made in the Far East [7].

From a financial standpoint there would be good reasons. Investments for chemical plants are supposed to be less than 50% of an installation in the western world. Wages in China are only a fraction of headcount costs in Switzerland. Projects can be done quickly through mobilization of almost unlimited manpower and through unbureaucratic ways of doing business.

Looking first at the reasons why installation costs are much lower, it becomes evident that the standards are not the same.

A chemical plant in the Far East would not have the same level of automation. In terms of investment the degree of automation plays an important role. Having an unlimited workforce on hand, it is certainly not necessary to avoid manual operation. However, the benefit of stable running processes with constant quality and high yields can probably not be reached without automation. By using the same degree of automation, the investment cost for a plant in the Far East would go up substantially.

Safety standards in the Far East are often behind the standards of the western world, where risk management provides safe working environments and minimizes the risk of business interruptions.

In addition, environmental standards of chemical plants in the Far East do not always foster sustainable development as defined in Kyoto.

Since DSM [8] would not go below a corporate-defined safety and environmental standard, the investment would be higher compared to certain local producers.

There is also a political dimension with uncertainties of political developments and partnerships which must be kept in mind when making a decision.

However, it would be wrong to apply these arguments in general, regardless of the kind of process, the local situation and the level of standard required. It is fair to say that in the case of labor-intensive processes at the beginning of the value chain production sites in the western world will have increasing difficulties to be competitive in the future.

In the case of the VITEX investment, the decision is still valid and comprehensible in the light of today's general conditions. As a high-tech process at the end of the value chain with a small headcount fraction of the overall manufacturing costs, it still makes sense to have the plant built in Switzerland. In addition, the above-mentioned success factors with emphasis on highly skilled and motivated people were almost a guarantee for speed and success of the project's implementation.

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