GreenDiol

Made in and from Nature (The Greenest),
for Humans and Nature (Multi-Beneficial Functions)

I. Company Introduction

GS

Grow Sustainably

GS Group is leading the change for a sustainable future

- Total assets: US$ 63 bil.
- Sales: US$ 72 bil.
- **Employees: 33,000**
- Overseas presence: 32 Countries
- **Overseas corporations and branches: 93 Global Sites**
- Subsidiaries: 67 ('22)

Business Area

Energy & Power

GS Energy

- LNG
- Power E&P

GS Caltex

- **Petroleum**
- **Petrochemicals**
- **Base oil**
- **Lubricants**
- **Gas stations**

GS Power

- Electric Power
- District heating & Cooling
- Renewable Energy

GS E&R

- Combined heat & power
- Coal-fired
- Renewable Energy

GS EPS

- Electricity
- Power Plant
- Bio-mass
- Wind power
- Fuel cell power

Retail & Trading

GS Retail

- Convenience store
- Supermarket
- TV & Mobile shopping

GS Global

- International Trading

Construction & Service

GS E&C

- Plant
- Construction
- Infrastructure

GS Sports

- FC Seoul football
- Seoul Kixx volleyball

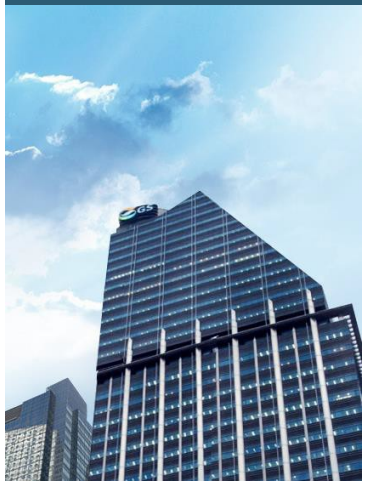
GS Caltex

I am your Energy

Leading energy and chemical enterprise in the global market

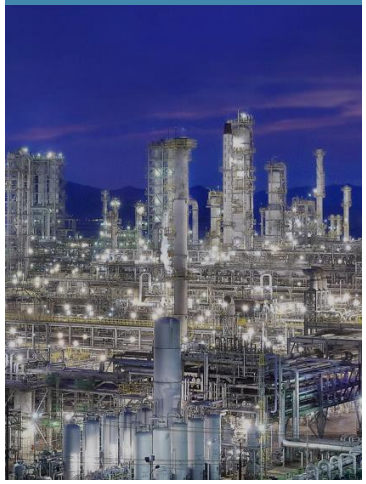
Business Area

Overview



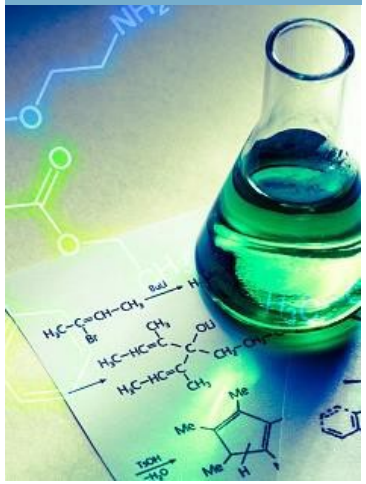
Revenue	**US$ 58.5 bil. ('22)**
Operating Income	US$ 4.0 bil. ('22)
Employees	**~3,200 persons**

Oil Refinery



Refining	**800,000 BD (World's 4th largest)**
Heavy Oil Upgrade	275,000 BD (No.1 in Korea)
Base Oil	26,000 BD

Petrochemical



Aromatics	2,800 KT/yr
Ethylene	750 KT/yr
Polyethylene	500 KT/yr
Polypropylene	180 KT/yr

To be the most respected energy & chemical company through Business, Digital & **Green Transformation**

GS Caltex

Green Transformation through 4 sectors

Biochemicals with diols (2,3-BDO, 1,3-PDO) & acids (3-HP)

Green Transformation Area

Biofuel

By producing biofuels from biomass, a sustainable feedstock, we contribute to reducing greenhouse gas emissions by replacing products produced from conventional fossil fuels

- Bio Jet Fuel
- Bio Marine Oil
- Bio Diesel

H_2,CCUS

Expanding our hydrogen business in line with the trend of revitalizing the hydrogen economy and low-carbon policies

- Producing low carbon hydrogen
- Pre-occupying demand (mobility/fuel cell business)
- Building the CCUS infrastructure

Lower Carbon Business

Biochemical

Developing technologies to produce various biochemicals used in cosmetics, agriculture, and plastics through eco-friendly processes

- Bio Diols (2,3-BDO, 1,3-PDO)
- 3-Hydroxypropionic acid

Plastic Recycle

Since 2010, we have been conducting a circular business to recycle waste plastics into petrochemical raw materials and products through mechanical and chemical recycling

- Chemical Recycle
- Mechanical Recycle

Green Transformation with Biofuel, H_2/CCUS, Plastic Recycle & **Biochemical**

GS Caltex

White Bio Global Standard Builder

Achieving the GS Caltex Goal and its Lower Carbon Vision

Organization

White Bio Development Center

BioTechnology Team	BioProcess Team	Bio Demo Plant Team	BioSolution Team	Diols PJT Team
Biocatalyst & Fermentation Tech. Development • Microbes • Lab. Fermentation Optimization	Process Development & Scale-up engineering • Lab Downstream • Pilot Validation • Scale-up Design	Demo Plant Operation & Verification • Technical capacity availability for the commercial scale • Prototype production (for marketing)	Strategy & Business development • Market analysis • Market development • O/I Partnership	Commercialization • Biz. Model • Techno-Economic Analysis • Basic design PKG

Areas

Cosmetics & Personal care | Agriculture | Food & Beverages | Industrials

White Bio Development Center was established in 2022 &
~100 members are working for **Industrial Biotechnology**

GS Caltex

World's leading infrastructures
White Bio has started since 2006

History

- Start of GS Caltex's WhiteBio (2006)
  - Start of Biobutanol R&D
- Start of 2,3-BDO R&D (2009)
- GS Bio Establishment (2010)
- Pilot plant (2010 ~ Present)
  - Biobutanol (2010~2015)
  - 2,3-BDO (2013~2014)
- Gunsan Demo plant (2015 ~ Present)
  - Plant design & Construction (2015~2019)
  - Operation (2019~Present)
- Yeosu Demo plant (2016 ~ Present)
  - Plant design & Construction (2016~2017)
  - Commissioning & prototype production (2018)
- Start of 3-HP R&D (2021 ~ Present)
- Open Innovation **(2021~ Present)**
  - Collaboration with partners (~ Present)

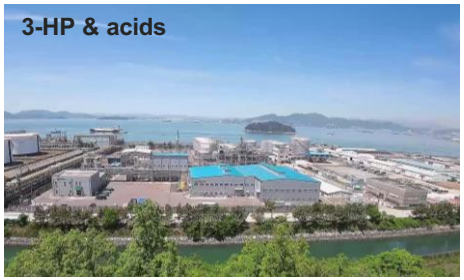
Infrastructure

0 Headquarter

1 R&D Center

2 2,3-BDO & diols

3 3-HP & acids



GS Caltex has developed the modest and standardized **Bio Demonstration Plant**

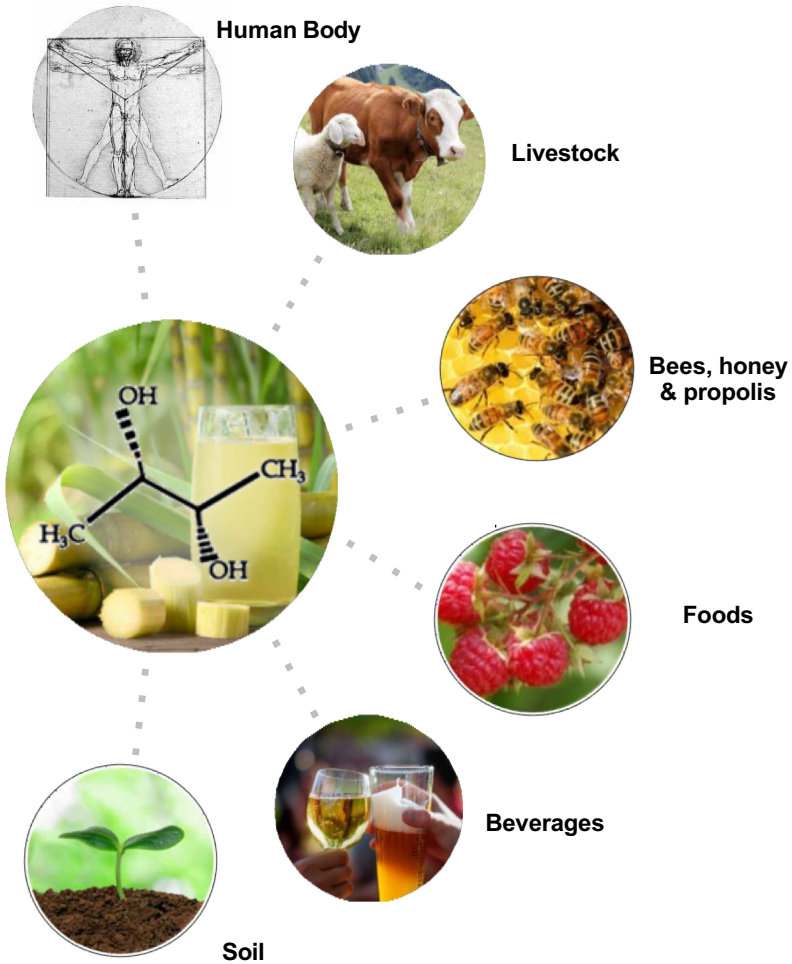
GS Caltex

II. 2,3-Butanediol from Nature

There is a reason for everything that exists in universe

2,3-Butanediol from Nature

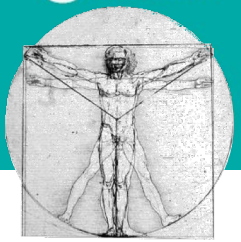
2,3-BDO has been found in humans, animals, and insects. It also exists in foods, animal feedstocks, and soil.



• **Human**	Body	2-20 uM	Human Metabolome Database (http://www.hmdb.ca/metabolites/HMDB03156)
• **Animals**	Sheep	Detected	Canadian Journal of Animal Science (1981) 61:649-656
	Rabbit		The Biochemical Journal (1954) 57: 177-180
	Cat		The Biochemical Journal (1954) 57: 180-185
	Fish	0.006 mg/kg	The EFSA Journal (2004) 166
	Livestock feeds	0.5-24 g/kg	Canadian Journal of Animal Science (1981) 61:649-656 Journal of the Science of Food and Agriculture (1973) 24: 613-648.
• **Insects**	Bee	Detected	Journal of apicultural science (2006) 50(2):115-126 Evidence-Based Compl and Alter Med (2009) 6(1):113-121
• **Foods & Beverages**	Wine	~ 2,900 mg/kg	The EFSA Journal (2004) 166
		527.9 μg/L	Molecules (2010) 15 : 9184-9196
		1,200 μg/L	Eur Food Res Technol (2008) 227:287-292
	Vinegar	~ 850 mg/kg	The EFSA Journal (2004) 166
	Cheddar cheese	~ 90 mg/kg	The EFSA Journal (2004) 166
	Beer	50 ~ 150 mg/L	Beer Composition and Properties, Beer in Health and Disease Prevention (2008) 222
	Makgeolli (Rice wine)	Detected	Molecules (2013) 18:5317-5325
	Fermented Pastes	Detected	Food Engineering Progress (2014) 18(3):248-255 Food Engineering Progress (2014) 18(4):300-306 Korean Journal of Food Preservation (2017) 24(2):187-195
	Kimchi	Probability	Journal of microbiology and biotechnology (1997) 7(1):68-74
	Fermented Beef jerky	2.79%	Polish Journal of Food and Nutrition Sciences (2016) 66(1):25-30
	Raspberry	~ 2.3 mg/kg	The EFSA Journal (2004) 166
	Coconut oil	Detected	Journal of Food Science (2015) 80(1):49-54
	Propolis, Honey	~ 52.05%	Inter J of Pharma and Bio Sciences (2015) 6(2):374-380 Zeitschrift für Naturforschung C (2002) 57:395-402
• **Soil**		Detected	Plant, Cell and Environment (2014) 37:813-826

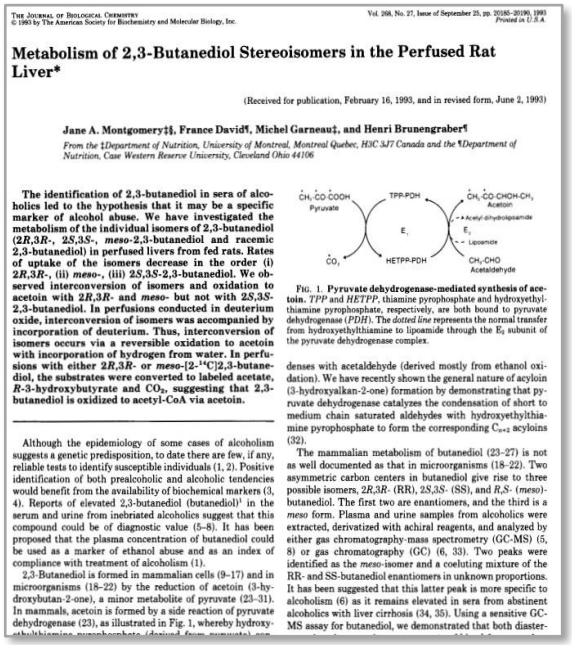
GS Caltex

For Humans



2,3-BDO has positive effects on human body.

Detoxifying agent in liver, Boosting immunity, Treating inflammation.



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Metabolism of 2,3-Butanediol Stereoisomers in the Perfused Rat Liver*

(Received for publication, February 16, 1993, and in revised form, June 2, 1993)

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The identification of 2,3-butanediol in sera of alcoholics led to the hypothesis that it may be a specific marker of alcohol abuse. We have investigated the metabolism of the individual isomers of 2,3-butanediol (2*R*,3*R*-, 2*S*,3*S*-, *meso*-2,3-butanediol and racemic 2,3-butanediol) in perfused livers from fed rats. Rates of uptake of the isomers decrease in the order (i) 2*R*,3*R*-, (ii) *meso*-, (iii) 2*S*,3*S*-2,3-butanediol. We observed interconversion of isomers and oxidation to acetoin with 2*R*,3*R*- and *meso*- but not with 2*S*,3*S*-2,3-butanediol. In perfusions conducted in deuterium oxide, interconversion of isomers was accompanied by incorporation of deuterium. Thus, interconversion of isomers occurs via a reversible oxidation to acetoin with incorporation of hydrogen from water. In perfusions with either 2*R*,3*R*- or *meso*-[2-^{14}C]2,3-butanediol, the substrates were converted to labeled acetate, *R*-3-hydroxybutyrate and CO_2, suggesting that 2,3-butanediol is oxidized to acetyl-CoA via acetoin.

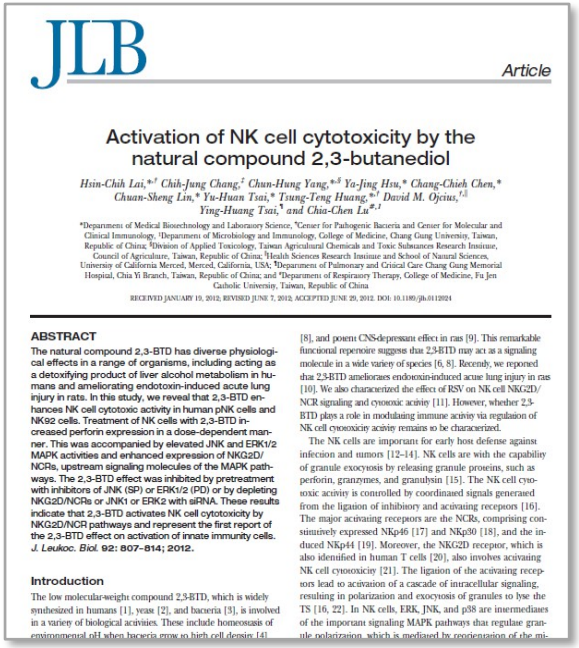
Although the epidemiology of some cases of alcoholism suggests a genetic predisposition, to date there are few, if any, reliable tests to identify susceptible individuals (1, 2). Positive identification of both presalcoholic and alcoholic tendencies would benefit from the availability of biochemical markers (3, 4). Reports of elevated 2,3-butanediol (butanediol)[1] in the serum and urine from inebriated alcoholics suggest that this compound could be of diagnostic value (5–8). It has been proposed that the plasma concentration of butanediol could be used as a marker of ethanol abuse and as an index of compliance with treatment of alcoholism (1).

2,3-Butanediol is formed in mammalian cells (9–17) and in microorganisms (18–22) by the reduction of acetoin (3-hydroxybutan-2-one), a minor metabolite of pyruvate (23–31). In mammals, acetoin is formed by a side reaction of pyruvate dehydrogenase (23), as illustrated in Fig. 1, whereby hydroxyethylthiamine pyrophosphate (derived from pyruvate) ...

FIG. 1. **Pyruvate dehydrogenase-mediated synthesis of acetoin.** *TPP* and *HETPP*, thiamine pyrophosphate and hydroxyethylthiamine pyrophosphate, respectively, are both bound to pyruvate dehydrogenase (*PDH*). The *dotted line* represents the normal transfer from hydroxyethylthiamine to lipoamide through the E_2 subunit of the pyruvate dehydrogenase complex.

denses with acetaldehyde (derived mostly from ethanol oxidation). We have recently shown the general nature of acyloin (3-hydroxyalkan-2-one) formation by demonstrating that pyruvate dehydrogenase catalyzes the condensation of short to medium chain saturated aldehydes with hydroxyethylthiamine pyrophosphate to form the corresponding C_{n+2} acyloins (32).

The mammalian metabolism of butanediol (23–27) is not as well documented as that in microorganisms (18–22). Two asymmetric carbon centers in butanediol give rise to three possible isomers, 2*R*,3*R*- (RR), 2*S*,3*S*- (SS), and *R*,*S*- (*meso*)-butanediol. The first two are enantiomers, and the third is a *meso* form. Plasma and urine samples from alcoholics were extracted, derivatized with achiral reagents, and analyzed by either gas chromatography-mass spectrometry (GC-MS) (5, 8) or gas chromatography (GC) (6, 33). Two peaks were identified as the *meso*-isomer and a coeluting mixture of the RR- and SS-butanediol enantiomers in unknown proportions. It has been suggested that this latter peak is more specific to alcoholism (6) as it remains elevated in sera from abstinent alcoholics with liver cirrhosis (34, 35). Using a sensitive GC-MS assay for butanediol, we demonstrated that both diaster-



JLB Article

Activation of NK cell cytotoxicity by the natural compound 2,3-butanediol

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ABSTRACT

The natural compound 2,3-BTD has diverse physiological effects in a range of organisms, including acting as a detoxifying product of liver alcohol metabolism in humans and ameliorating endotoxin-induced acute lung injury in rats. In this study, we reveal that 2,3-BTD enhances NK cell cytotoxic activity in human pNK cells and NK92 cells. Treatment of NK cells with 2,3-BTD increased perforin expression in a dose-dependent manner. This was accompanied by elevated JNK and ERK1/2 MAPK activities and enhanced expression of NKG2D/NCRs, upstream signaling molecules of the MAPK pathways. The 2,3-BTD effect was inhibited by pretreatment with inhibitors of JNK (SP) or ERK1/2 (PD) or by depleting NKG2D/NCRs or JNK1 or ERK2 with siRNA. These results indicate that 2,3-BTD activates NK cell cytotoxicity by NKG2D/NCR pathways and represent the first report of the 2,3-BTD effect on activation of innate immunity cells. *J. Leukoc. Biol.* **92: 807–814; 2012.**

Introduction

The low molecular-weight compound 2,3-BTD, which is widely synthesized in humans [1], yeast [2], and bacteria [3], is involved in a variety of biological activities. These include homeostasis of environmental pH when bacteria grow to high cell density [4], [8], and potent CNS-depressant effect in rats [9]. This remarkable functional repertoire suggests that 2,3-BTD may act as a signaling molecule in a wide variety of species [6, 8]. Recently, we reported that 2,3-BTD ameliorates endotoxin-induced acute lung injury in rats [10]. We also characterized the effect of RSV on NK cell NKG2D/NCR signaling and cytotoxic activity [11]. However, whether 2,3-BTD plays a role in modulating immune activity via regulation of NK cell cytotoxicity activity remains to be characterized.

The NK cells are important for early host defense against infection and tumors [12–14]. NK cells are with the capability of granule exocytosis by releasing granule proteins, such as perforin, granzymes, and granulysin [15]. The NK cell cytotoxic activity is controlled by coordinated signals generated from the ligation of inhibitory and activating receptors [16]. The major activating receptors are the NCRs, comprising constitutively expressed NKp46 [17] and NKp30 [18], and the induced NKp44 [19]. Moreover, the NKG2D receptor, which is also identified in human T cells [20], also involves activating NK cell cytotoxicity [21]. The ligation of the activating receptors lead to activation of a cascade of intracellular signaling, resulting in polarization and exocytosis of granules to lyse the TS [16, 22]. In NK cells, ERK, JNK, and p38 are intermediates of the important signaling MAPK pathways that regulate granule polarization, which is mediated by reorganization of the mi-

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Microbes and Infection 9 (2007) 1402–1409

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Original article

The bacterial metabolite 2,3-butanediol ameliorates endotoxin-induced acute lung injury in rats

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Abstract

Widely identified in bacteria, yeasts and human beings, 2,3-butanediol has been studied for decades.This chemical reportedly functions as a neutralization agent to counteract lethal acidification by bacterial growth and as a signaling molecule involved in interactions among insects, and between bacteria and the plant host. While 2,3-butanediol is produced by many pathogenic bacterial species, its significance and effect on mammals remains basically uncharacterized. Herein, we show that gastric intubation of 2,3-butanediol in rats significantly ameliorates acute lung injury (ALI) and the inflammatory responses induced by the bacterial endotoxin lipopolysaccharide (LPS), with an efficacy comparable to that of the polyphenol compound resveratrol. Such effect was further demonstrated to occur via modulation of the NF-κB signaling pathway. These results indicate that bacterial metabolite, 2,3-butanediol has a negative regulatory effect on host innate immunity response, suggesting bacteria may use some metabolites for host immune evasion.

Keywords: 2,3-butanediol; LPS; NF-κB; Acute lung injury; Inflammation

1. Introduction

The capacity for production of the low-molecular-weight hydrocarbon, 2,3-butanediol, from pyruvate has been widely identified in different bacterial species, including all species of *Serratia* and *Enterobacter*, as well as some species of *Klebsiella*, *Erwinia*, *Bacillus* and *Aeromonas* [1]. Previous studies densities, regulation of the cellular NAD/NADH ratio in bacteria [2], an agent for storage of organs such as the liver [1], a biomarker for yeast strain differentiation [3], and a plasma biomarker of ethanol abuse and an index of compliance in alcoholism treatment [4]. The derivatives of 2,3-butanediol, including liquid fuel additives, anti-freeze agents, food flavorings, solvents and plastics, are also widely used in industry [1].

Channeling Metabolism

2,3-butanediol serves as a detoxifying product in liver

Boosting Immune System

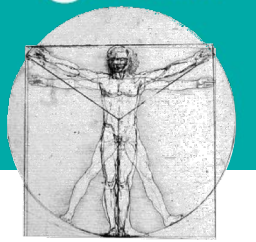
2,3-butanediol enhances immunity by activating innate immunity cells

Controlling Inflammation

2,3-butanediol ameliorates endotoxin-induced lung injury

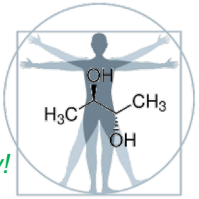
GS Caltex

For Humans

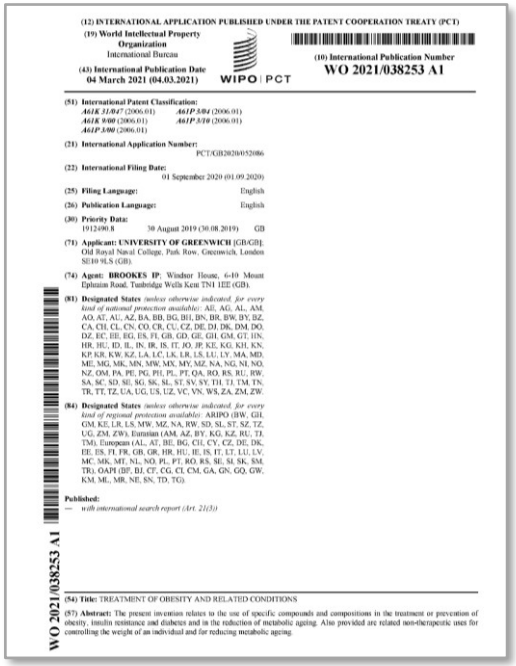


A patent about the usage of 2,3-BDO in treatment or prevention of obesity, insulin resistance, and diabetes and in the reduction of metabolic ageing has been issued (’21).

2,3-BDO treatment has shown good biocompatibility and durability.



Reasons for 2,3-BDO in our body!



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(54) Title: TREATMENT OF OBESITY AND RELATED CONDITIONS

(57) Abstract: The present invention relates to the use of specific compounds and compositions in the treatment or prevention of obesity, insulin resistance and diabetes and in the reduction of metabolic ageing. Also provided are related non-therapeutic uses for controlling the weight of an individual and for reducing metabolic ageing.

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Treatment of wild-type mice with 2,3-butanediol, a urinary biomarker of *Fmo5*$^{-/-}$ mice, decreases plasma cholesterol and epididymal fat deposition

Sunil Veeravalli[1], Dorsa Varshavi[2†], Flora H. Scott[3], Dorna Varshavi[2†], Frank S. Pullen[2†], Kirill Veselkov[3], Ian R. Phillips[1,4], Jeremy R. Everett[2*‡] and Elizabeth A. Shephard[1*]

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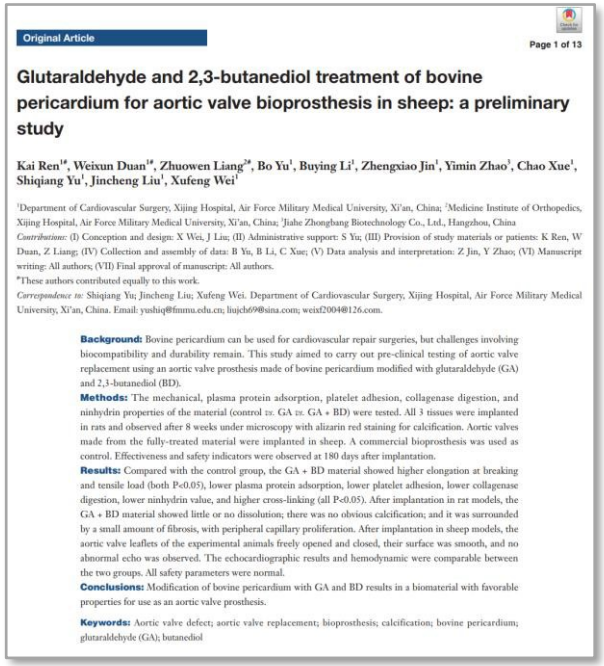
We previously showed that *Fmo5*$^{-/-}$ mice exhibit a lean phenotype and slower metabolic ageing. Their characteristics include lower plasma glucose and cholesterol, greater glucose tolerance and insulin sensitivity, and a reduction in age-related weight gain and whole-body fat deposition. In this paper, nuclear magnetic resonance (NMR) spectroscopy-based metabolite analyses of the urine of *Fmo5*$^{-/-}$ and wild-type mice identified two isomers of 2,3-butanediol as discriminating urinary biomarkers of *Fmo5*$^{-/-}$ mice. Antibiotic-treatment of *Fmo5*$^{-/-}$ mice increased plasma cholesterol concentration and substantially reduced urinary excretion of 2,3-butanediol isomers, indicating that the gut microbiome contributed to the lower plasma cholesterol of *Fmo5*$^{-/-}$ mice, and that 2,3-butanediol is microbially derived. Short- and long-term treatment of wild-type mice with a 2,3-butanediol isomer mix decreased plasma cholesterol and epididymal fat deposition but had no effect on plasma concentrations of glucose or insulin, or on body weight. In the case of long-term treatment, the effects were maintained after withdrawal of 2,3-butanediol. Short-, but not long-term treatment, also decreased plasma concentrations of triglycerides and non-esterified fatty acids. Fecal transplant from *Fmo5*$^{-/-}$ to wild-type mice



Original Article

Page 1 of 13

Glutaraldehyde and 2,3-butanediol treatment of bovine pericardium for aortic valve bioprosthesis in sheep: a preliminary study

Kai Ren[1#], Weixun Duan[1#], Zhuowen Liang[2#], Bo Yu[1], Buying Li[1], Zhengxiao Jin[1], Yimin Zhao[3], Chao Xue[1], Shiqiang Yu[1], Jincheng Liu[1], Xufeng Wei[1]

[1]Department of Cardiovascular Surgery, Xijing Hospital, Air Force Military Medical University, Xi'an, China; [2]Medicine Institute of Orthopedics, Xijing Hospital, Air Force Military Medical University, Xi'an, China; [3]Jiahe Zhongbang Biotechnology Co., Ltd., Hangzhou, China

Contributions: (I) Conception and design: X Wei, J Liu; (II) Administrative support: S Yu; (III) Provision of study materials or patients: K Ren, W Duan, Z Liang; (IV) Collection and assembly of data: B Yu, B Li, C Xue; (V) Data analysis and interpretation: Z Jin, Y Zhao; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

#These authors contributed equally to this work.

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Background: Bovine pericardium can be used for cardiovascular repair surgeries, but challenges involving biocompatibility and durability remain. This study aimed to carry out pre-clinical testing of aortic valve replacement using an aortic valve prosthesis made of bovine pericardium modified with glutaraldehyde (GA) and 2,3-butanediol (BD).

Methods: The mechanical, plasma protein adsorption, platelet adhesion, collagenase digestion, and ninhydrin properties of the material (control *vs.* GA *vs.* GA + BD) were tested. All 3 tissues were implanted in rats and observed after 8 weeks under microscopy with alizarin red staining for calcification. Aortic valves made from the fully-treated material were implanted in sheep. A commercial bioprosthesis was used as control. Effectiveness and safety indicators were observed at 180 days after implantation.

Results: Compared with the control group, the GA + BD material showed higher elongation at breaking and tensile load (both $P<0.05$), lower plasma protein adsorption, lower platelet adhesion, lower collagenase digestion, lower ninhydrin value, and higher cross-linking (all $P<0.05$). After implantation in rat models, the GA + BD material showed little or no dissolution; there was no obvious calcification; and it was surrounded by a small amount of fibrosis, with peripheral capillary proliferation. After implantation in sheep models, the aortic valve leaflets of the experimental animals freely opened and closed, their surface was smooth, and no abnormal echo was observed. The echocardiographic results and hemodynamic were comparable between the two groups. All safety parameters were normal.

Conclusions: Modification of bovine pericardium with GA and BD results in a biomaterial with favorable properties for use as an aortic valve prosthesis.

Keywords: Aortic valve defect; aortic valve replacement; bioprosthesis; calcification; bovine pericardium; glutaraldehyde (GA); butanediol

Preventing obesity, insulin resistance & diabetes

Decreasing cholesterol & fat

Improving biocompatibility & durability of transplants

III. 2,3-BDO manufactured by GS Caltex

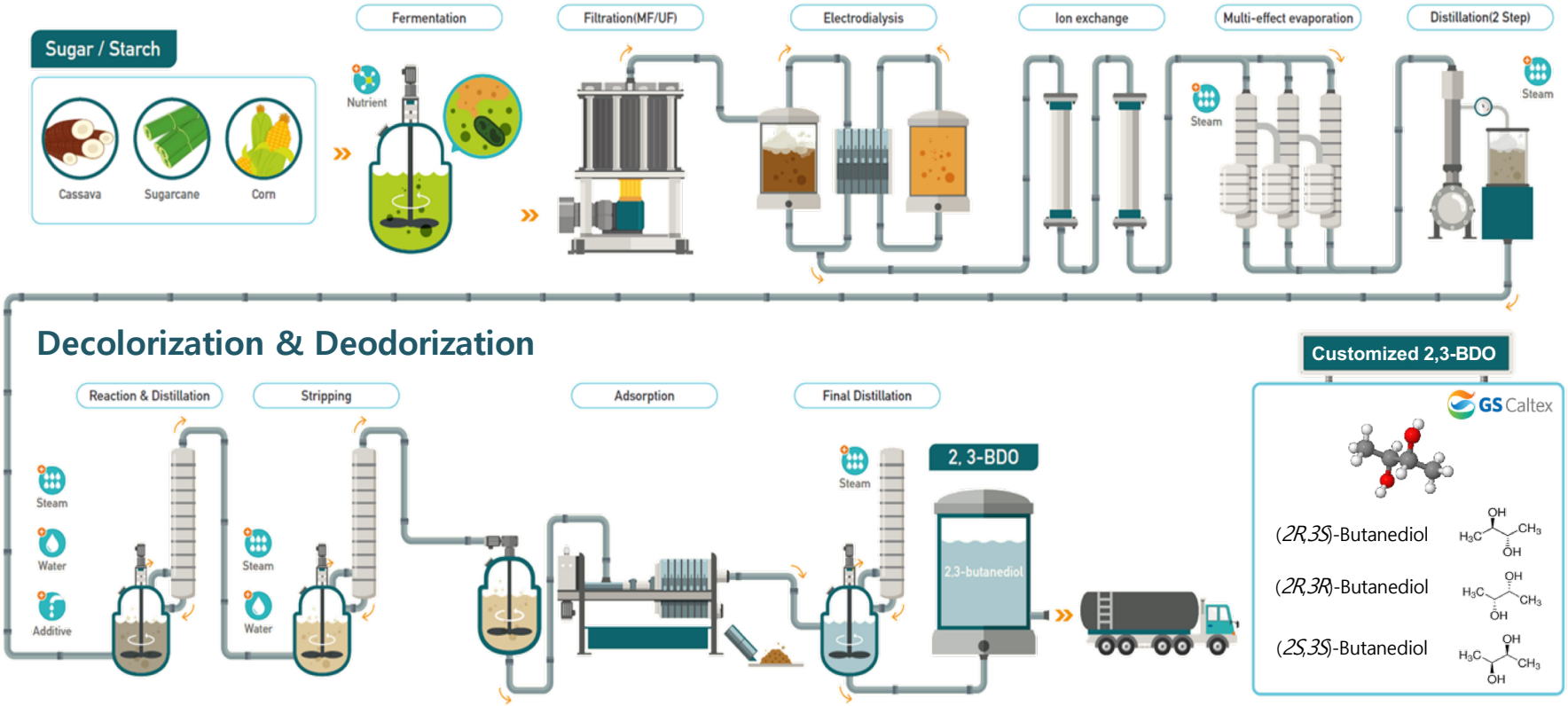
GS Caltex is the 1st & only bio-2,3-BDO mass producing company

2,3-BDO Production Process

GS Caltex is the first and only company enabling the mass production of high quality 2,3-BDO through microbial fermentation of eco-friendly biomasses.

Microorganisms & Fermentation

Separation & Purification



[cf. Chemical process for 2,3-BDO production]

Microbes

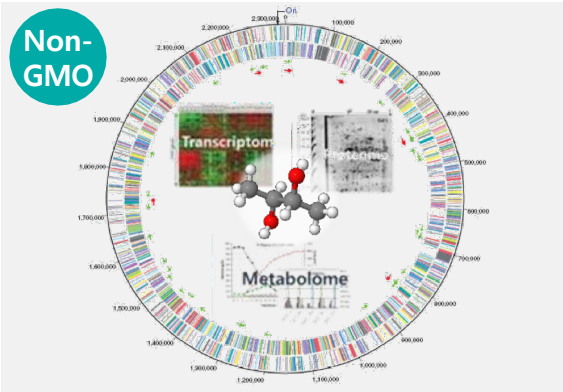
GS Caltex isolated 2,3-BDO-generating microbes from nature and has developed the most effective 2,3-BDO producer through eco-friendly ways.

2,3-BDO-generating Microbes

GS Caltex has tried to isolate 2,3-BDO-producing microbes **from nature** since 2009.

In 2012, GS Caltex isolated numerous 2,3-BDO producers from on the plain land of Daeduk precinct, South Korea.

Among them, GS Caltex screened microbes that are **greener** than the others.

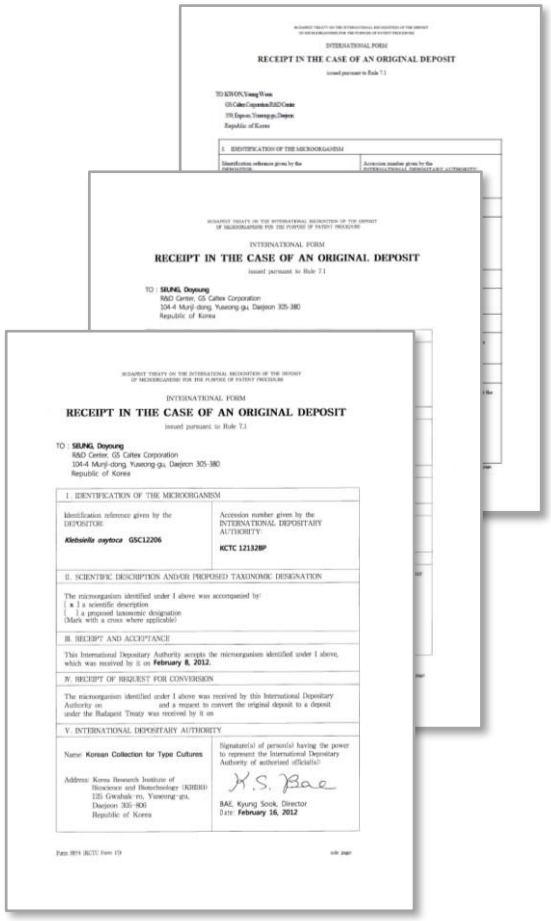


Best 2,3-BDO Producer

GS Caltex has sequenced the genome and characterized their physicochemical properties.

Then, the most effective and **eco-friendly 2,3-BDO producers** were selected for mass production.

These bacteria were registered to Korean Culture Type Collection (KCTC) as properties of GS Caltex.



INTERNATIONAL FORM

RECEIPT IN THE CASE OF AN ORIGINAL DEPOSIT

TO : SILING, Doyoung
R&D Center, GS Caltex Corporation
104-4 Munji-dong, Yuseong-gu, Daejeon 305-380
Republic of Korea

I. IDENTIFICATION OF THE MICROORGANISM

Identification reference given by the DEPOSITOR: *Klebsiella oxytoca* GSC12206

Accession number given by the INTERNATIONAL DEPOSITARY AUTHORITY: KCTC 12132BP

II. SCIENTIFIC DESCRIPTION AND/OR PROPOSED TAXONOMIC DESIGNATION

The microorganism identified under I above was accompanied by:
[x] a scientific description
[ ] a proposed taxonomic designation
(Mark with a cross where applicable)

III. RECEIPT AND ACCEPTANCE

This International Depositary Authority accepts the microorganism identified under I above, which was received by it on February 8, 2012.

IV. RECEIPT OF REQUEST FOR CONVERSION

The microorganism identified under I above was received by this International Depositary Authority on and a request to convert the original deposit to a deposit under the Budapest Treaty was received by it on

V. INTERNATIONAL DEPOSITARY AUTHORITY

Name: Korean Collection for Type Cultures

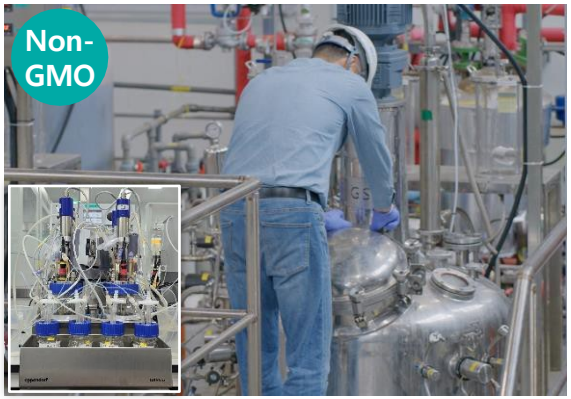
Address: Korea Research Institute of Bioscience and Biotechnology (KRIBB) 125 Gwahak-ro, Yuseong-gu, Daejeon 305-806 Republic of Korea

Signature(s) of person(s) having the power to represent the International Depositary Authority of authorized official(s): K.S. Bae

BAE, Kyung Sook, Director
Date: February 16, 2012

Technologies

GS Caltex has developed all core technologies making a breakthrough for the production and recovery of 2,3-BDO through microbial fermentation.



2,3-BDO Fermentation

GS Caltex has developed 2,3-BDO fermentation process using various biomasses, including **non-GMO starch- and sugar-based carbon sources**.

The **fermentation process** developed by GS Caltex enables high-level production of 2,3-BDO with minimum amounts of byproducts at a commercial scale.

2,3-BDO Recovery

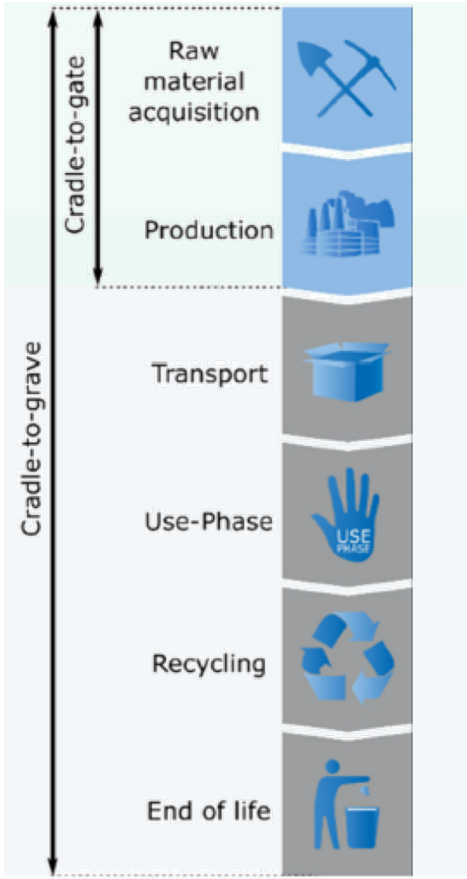
GS Caltex has developed core technologies for the **cost-effective** and **eco-friendly** 2,3-BDO recovery from fermentation broth.

The recovery process developed by GS Caltex never uses any toxic chemicals and enables to obtain exceedingly high quality of 2,3-BDO.

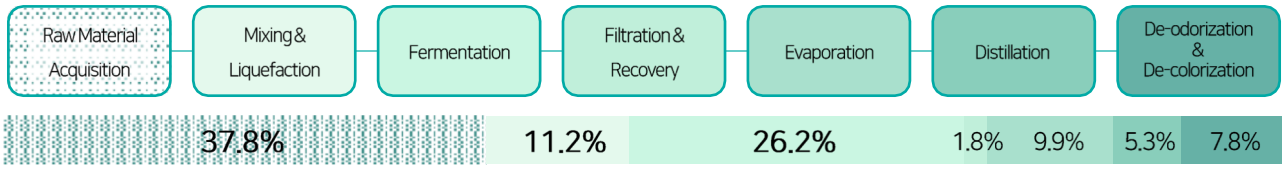
Life Cycle Assessment

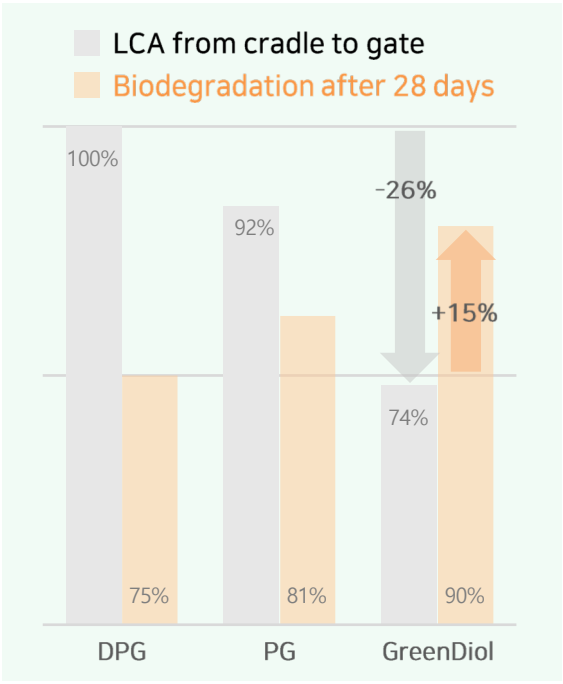
GS Caltex GreenDiol process reduces 18-26% of CO_2 emissions compared to fossil-based diols (e.g. DPG, PG) according to the method of ISO 14040/14044

LCA for GreenDiol



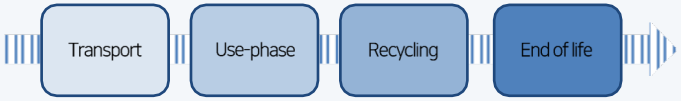
LCA from Cradle to Gate



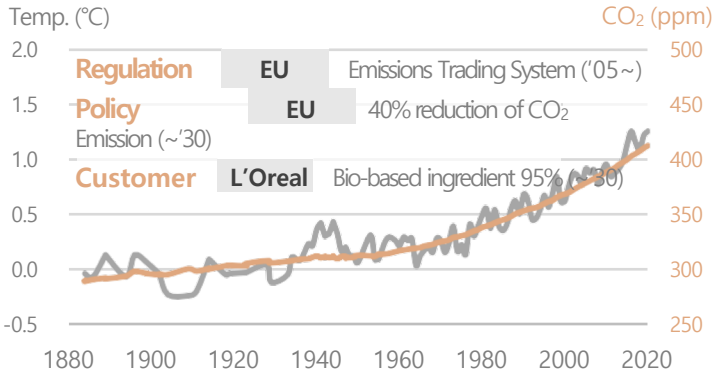


Additional LCA from Gate to Grave

(analysis on-going)



Additional reduction expected



Above results were generated by GS Caltex as of July '23, utilizing Ecoinvent and Sphera DB

Excellence & Sustainability

The excellence of technologies, processes, & 2,3-BDO has been officially recognized.

The sustainability of 2,3-BDO has been certified by many global organizations.

GS Caltex successfully registered 2,3-BDO to EU REACH.

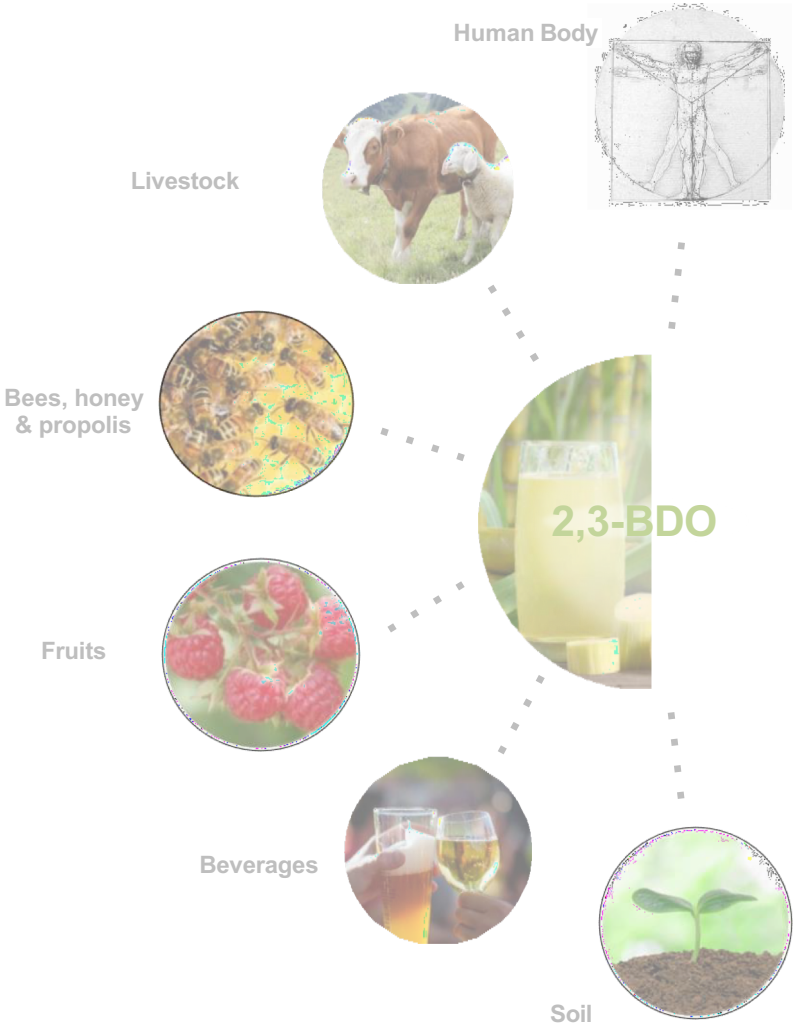
- ✓ COSMOS
- ✓ USDA
- ✓ NATRUE
- ✓ VEGAN
- ✓ EU REACH
- ✓ ISO16128: 100% Natural & Natural Origin
- ✓ EWG 1st Green Grade
- ✓ New Excellent Technology Award
- ✓ New Excellent Product Award
- ✓ Jang Young-Sil Award
- ✓ KSBB Award

IV. GS Caltex GreenDiol

GreenDiol is GS Caltex's trade name for 2,3-BDO

GreenDiol: From Nature to Skin

Based on 2,3-BDO's beneficial effects in nature, GS Caltex has successfully developed GreenDiol as the greenest, multi-functional cosmetic ingredient.



Nature to Skin

GreenDiol: The Greenest with Multi-functions

As expected, GreenDiol offers multi-layered functions, such as solubilization, unique texture, stabilization, etc., on skin and hair.

1. Solubilization	- High solubility for active ingredients - Better solubilization of ceramides than 1,3-BDO (10x) & DPG (2x) - Better dispersion of dyes than 1,3-BG
2. Unique texture	- Initial body texture - Quick absorption - Silky & less sticky
3. Stabilization	- Vitamin C stabilization - Alleviation of vitamin C discoloration
4. Anti-inflammation	- Reduction of redness - Inhibition of pro-inflammatory substances (NF-κB pathway)
5. Penetration	- More effective penetration than 1,3-BDO (4x amount & 2x depth)
6. Preservative boosting	- Superior preservative boosting than 1,3-BDO & 1,3-PDO (~20% more effective)
7. Moisturization	- Superior moisturizing capability than 1,3-BDO (8x) - Synergistic moisturizing effects with glycerin

GreenDiol in Cosmetics & Personal Care Products

Thanks to 2,3-BDO's unique & distinguished properties, many global cosmetic companies have been adopting GreenDiol for their products.

Dr. Jart+
Ceramidin cream

CNP
IP-BHA Ampoule

Dr. BangGiWon
Color Shampoo w/ salicylic acid

1. Solubility of Ingredients

- dissolving poorly soluble active ingredients (e.g. ceramides, salicylic acid, TECA)
- preventing precipitation
- dispersing dyes more effectively

cf. 1,3-BG , DPG, 1,3-PDO, glycerin

Givenchy
Le soin noir Serum

Whoo
Hwanyu Serum

RENE FURTERE
Detangling Hair Spray

2. Unique Texture

- creating unique initial body texture
- enabling quick absorption
- providing silky & less sticky texture
- suitable for serums with minimal oil content

Physiogel
Scienceuticals Serum

ISA KNOX
Vitamin Ampoule

PHÉNOTYP
Niacinamide (10%) & Polyphenols Serum

3. Stability of Vitamin C

- stabilizing vitamin C
- alleviating discoloration of vitamin C

GreenDiol: The Greenest with Multi-functions

Solubilization of GreenDiol

1. Solubilization	**- High solubility for active ingredients** **- Better solubilization of ceramides than 1,3-BDO (10x) & DPG (2x)** **- Better dispersion of dyes than 1,3-BDO**
2. Unique texture	- Initial body texture - Quick absorption - Silky & less sticky
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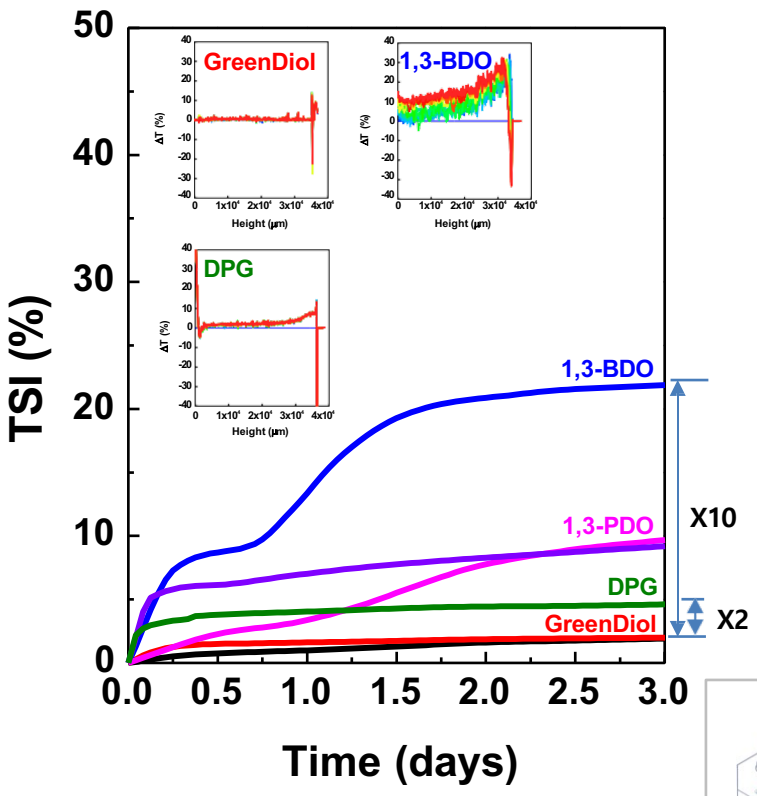
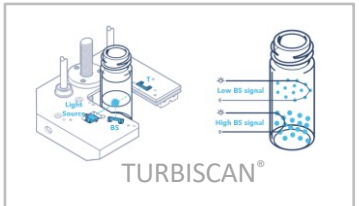
GreenDiol: The Greenest with Multi-functions

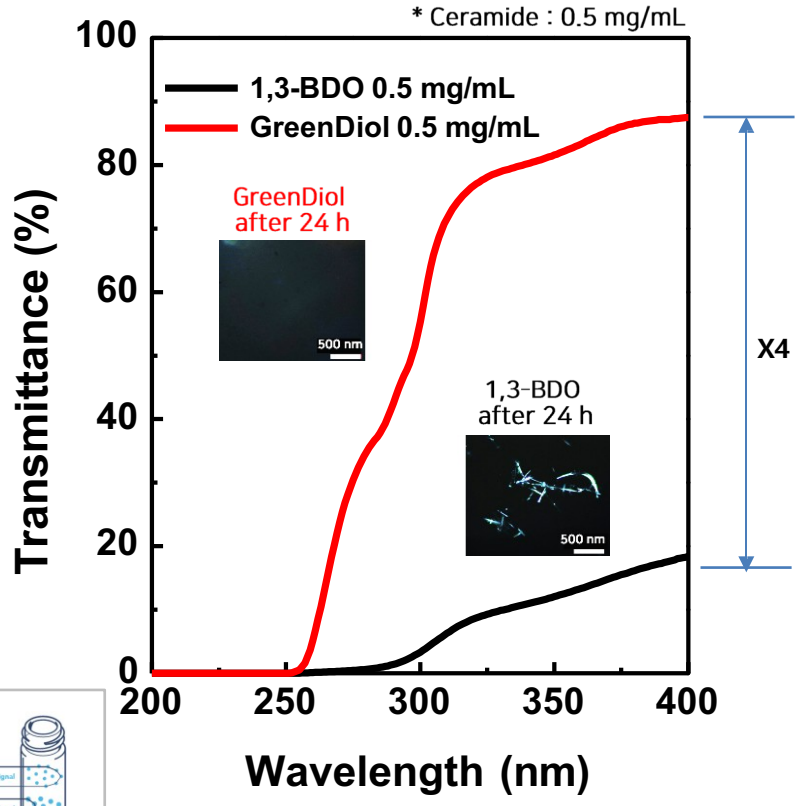
GreenDiol shows a remarkable solubility

- GreenDiol solubilizes ceramides better than 1,3-BDO (10x) & DPG (2x)
- Less ceramides are crystalized (4x) in 2,3-BDO compared to 1,3-BDO

GreenDiol enables developing high ceramide-containing end-products







Manuscript under revision

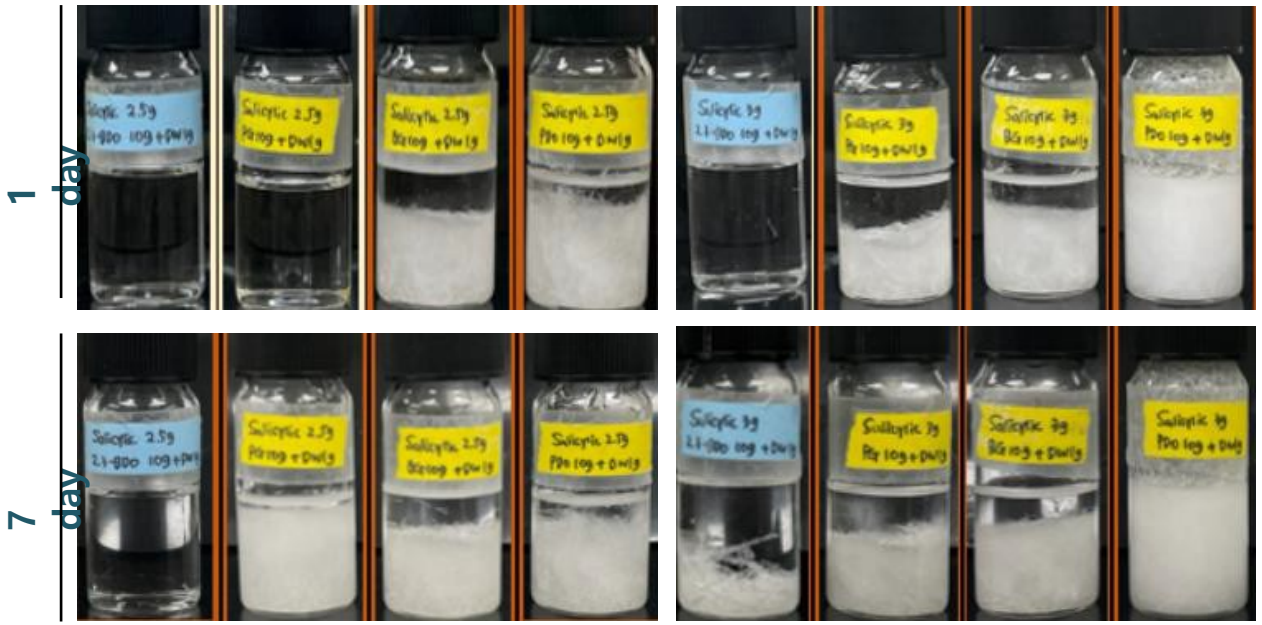
GreenDiol: The Greenest with Multi-functions

GreenDiol shows a remarkable solubility

- GreenDiol solubilizes salicylic acid better than other diols (PG, 1,3-BDO, 1,3-PDO)
- Furthermore, GreenDiol disperses colorants more effectively than 1,3-BDO

GreenDiol prevents the crystallization of salicylic acid

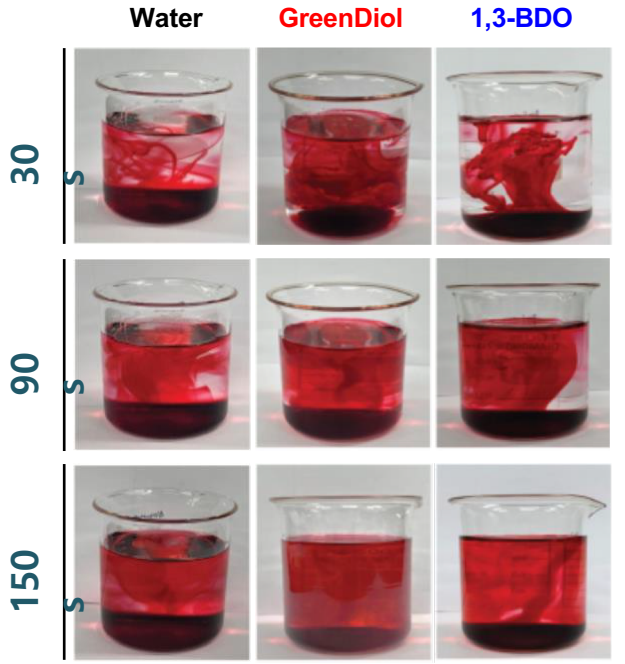
Solubilization of salicylic acid



19% Salicylic acid in diols

21% Salicylic acid in diols

Dispersion of dye



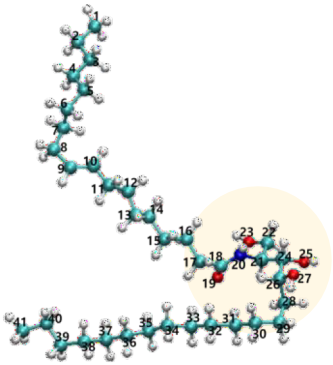
0.01% colorant in 5% diols

GreenDiol: The Greenest with Multi-functions

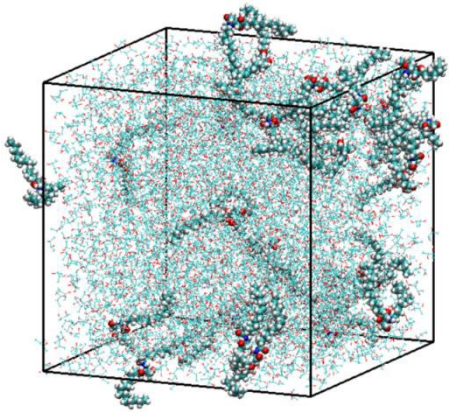
The high solubilizing capability of GreenDiol is supported by molecular simulation.

- More 2,3-BDO tends to attach to the head area of ceramides with a vertical angle than 1,3-BDO
- It leads to give more space between ceramide molecules, avoiding stacking & crystalizing

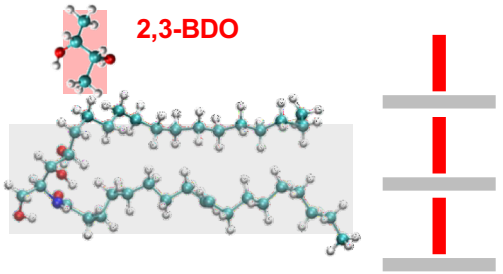
Atom index number



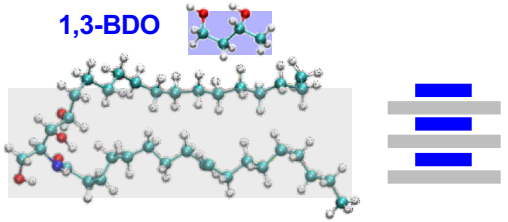
Computational simulation



Relative orientation of diols

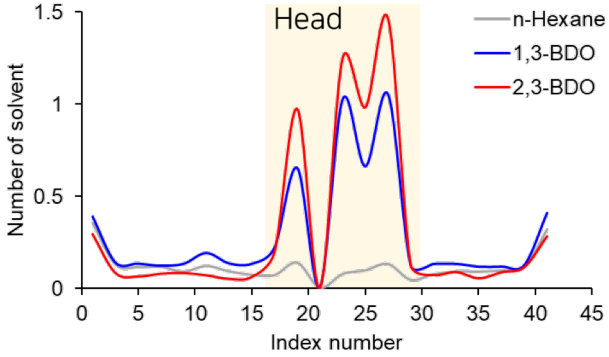


Vertical alignment

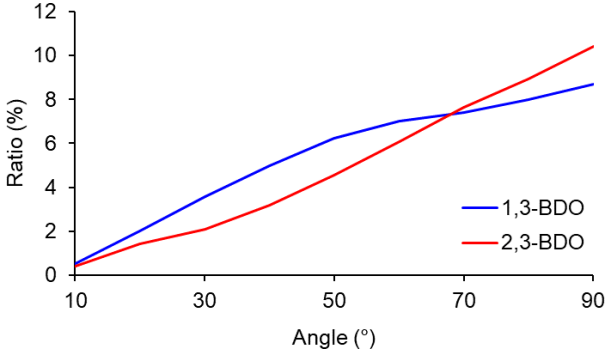


Horizontal alignment

Locations of interaction



Angle of interaction



Manuscript under revision

GreenDiol: The Greenest with Multi-functions

Unique Texture of GreenDiol

1. Solubilization	- High solubility for active ingredients - Better solubilization of ceramides than 1,3-BDO (10x) & DPG (2x) - Better dispersion of dyes than 1,3-BDO
2. Unique texture	**- Initial body texture** **- Quick absorption** **- Silky & less sticky**
3. Stabilization	- Vitamin C stabilization - Alleviation of vitamin C discoloration
4. Anti-inflammation	- Reduction of redness - Inhibition of pro-inflammatory substances (NF-κB pathway)
5. Penetration	- More effective penetration than 1,3-BDO (4x amount & 2x depth)
6. Preservative boosting	- Superior preservative boosting than 1,3-BDO & 1,3-PDO (~20% more effective)
7. Moisturization	- Superior moisturizing capability than 1,3-BDO (8x) - Synergistic moisturizing effects with glycerin

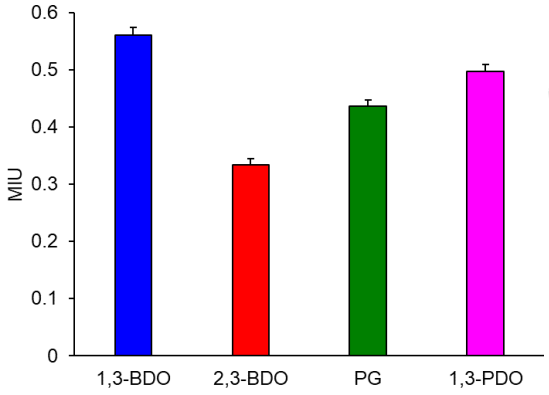
GreenDiol: The Greenest with Multi-functions

GreenDiol has unique texture

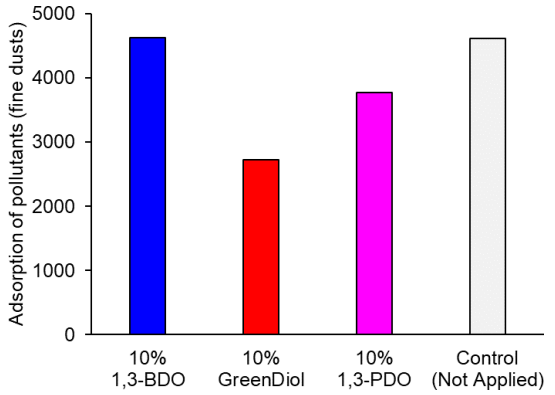
- Many chemists are trying to replace conventional polyols with GreenDiol due to its non-sticky finish
- Its non-sticky finish is supported by lower adsorption of pollutants/dusts on skin than other polyols

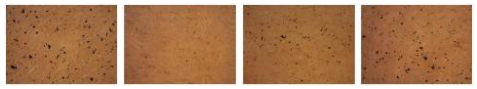
Serum with GreenDiol enables non-sticky and fast adsorption & silky-finish touch

Mean coefficient of friction

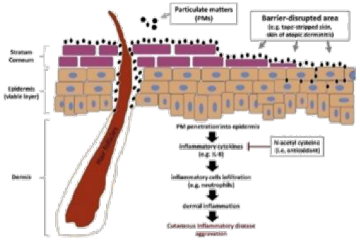


Pollutants/dusts adsorption





GreenDiol gives outstanding non-sticky feels to my serum products.



GreenDiol: The Greenest with Multi-functions

Stabilization by GreenDiol

1. Solubilization	- High solubility for active ingredients - Better solubilization of ceramides than 1,3-BDO (10x) & DPG (2x) - Better dispersion of dyes than 1,3-BDO
2. Unique texture	- Initial body texture - Quick absorption - Silky & less sticky
3. Stabilization	**- Vitamin C stabilization** **- Alleviation of vitamin C discoloration**
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7. Moisturization	- Superior moisturizing capability than 1,3-BDO (8x) - Synergistic moisturizing effects with glycerin

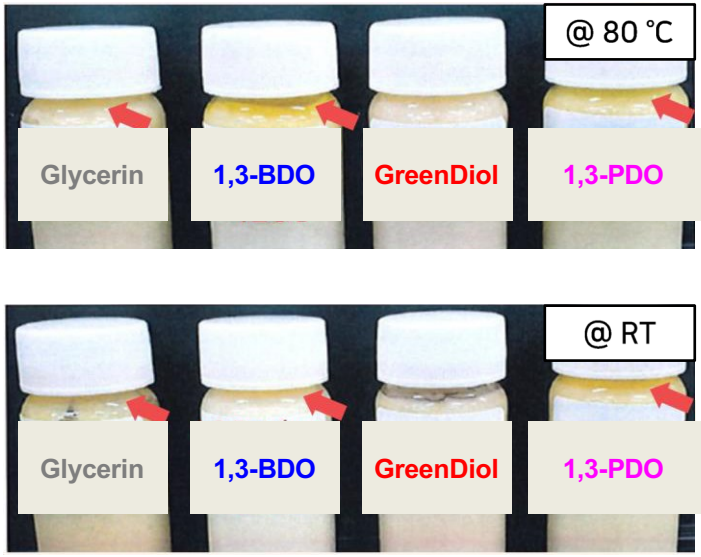
GreenDiol: The Greenest with Multi-functions

GreenDiol stabilizes vitamin C in cosmetic products

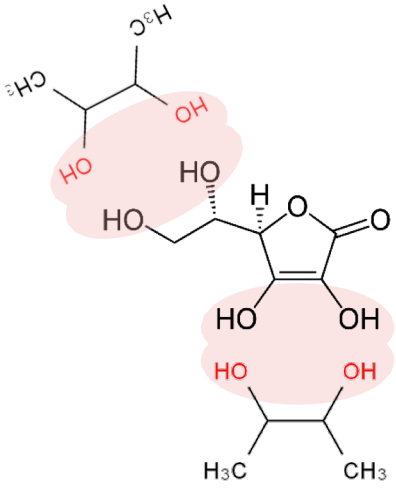
- The distances within the –OH group pairs of 2,3-BDO and vitamin C are much more similar than those of 1,3-BDO and 1,3-PDO.
- It seems for 2,3-BDO to effectively repress discoloration of vitamin C in cosmetic products

GreenDiol extends the period of storage for vitamin-containing formulation

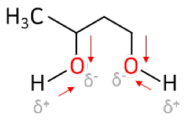
Stability of formulas with vitamin C in GreenDiol



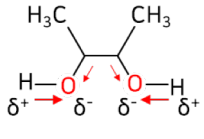
Distance within –OH group pairs of 2,3-BDO & vitamin C



So, we are replacing DPG & 1,3-PDO with GreenDiol for vitamin C serum.



1,3-BDO



2,3-BDO

GreenDiol: The Greenest with Multi-functions

Anti-inflammation by GreenDiol

1. Solubilization	- High solubility for active ingredients - Better solubilization of ceramides than 1,3-BDO (10x) & DPG (2x) - Better dispersion of dyes than 1,3-BDO
2. Unique texture	- Initial body texture - Quick absorption - Silky & less sticky
3. Stabilization	- Vitamin C stabilization - Alleviation of vitamin C discoloration
4. Anti-inflammation /soothing	**- Reduction of redness - Inhibition of pro-inflammatory substances (NF-κB pathway)**
5. Penetration	- More effective penetration than 1,3-BDO (4x amount & 2x depth)
6. Preservative boosting	- Superior preservative boosting than 1,3-BDO & 1,3-PDO (~20% more effective)
7. Moisturization	- Superior moisturizing capability than 1,3-BDO (8x) - Synergistic moisturizing effects with glycerin

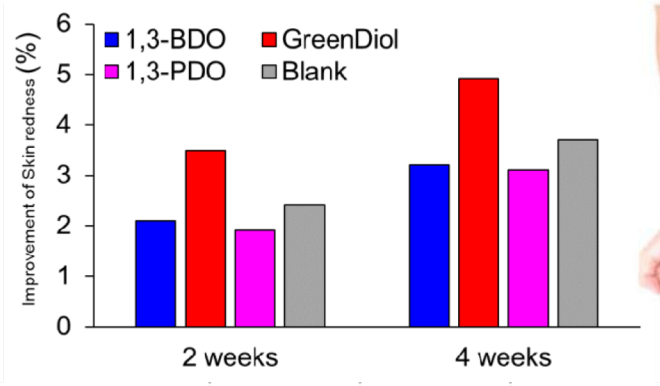
GreenDiol: The Greenest with Multi-functions

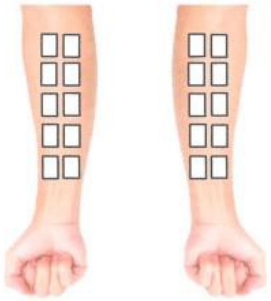
GreenDiol represses inflammation on skin (soothing)

- 2,3-BDO has significantly superior anti-inflammatory effects than 1,3-BDO and 1,3-PDO
- GreenDiol can give higher anti-inflammatory effect with similar cost of active ingredient (D-panthenol)

GreenDiol replaces conventional anti-inflammation agents

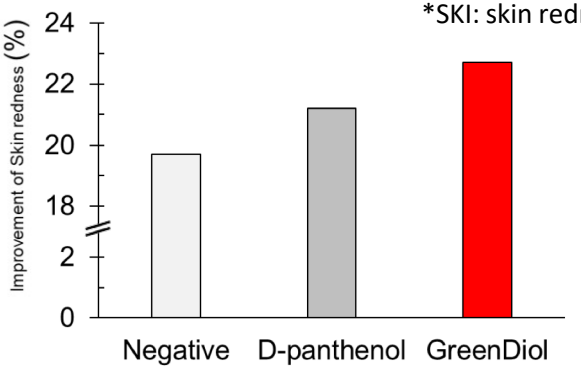
SKI: with different diols

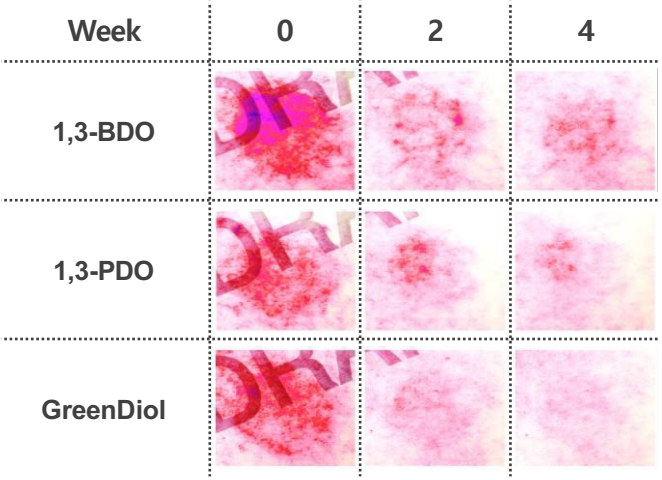




SKI: with active ingredients

*SKI: skin redness improvement





INCI name	Formula (%)		
	Negative	D-Panthenol	GreenDiol
Water	95.21	94.21	89.66
Disodium EDTA	0.02	0.02	0.02
Carbomer	0.14	0.14	0.14
Glycerin	3.00	3.00	3.00
Hydroxyethylcellulose	0.02	0.02	0.02
Dexpanthenol	-	1.00	-
GreenDiol	-	-	5.55
Tromethamine	0.11	0.11	0.11
1,2-Hexanediol	1.50	1.50	1.50

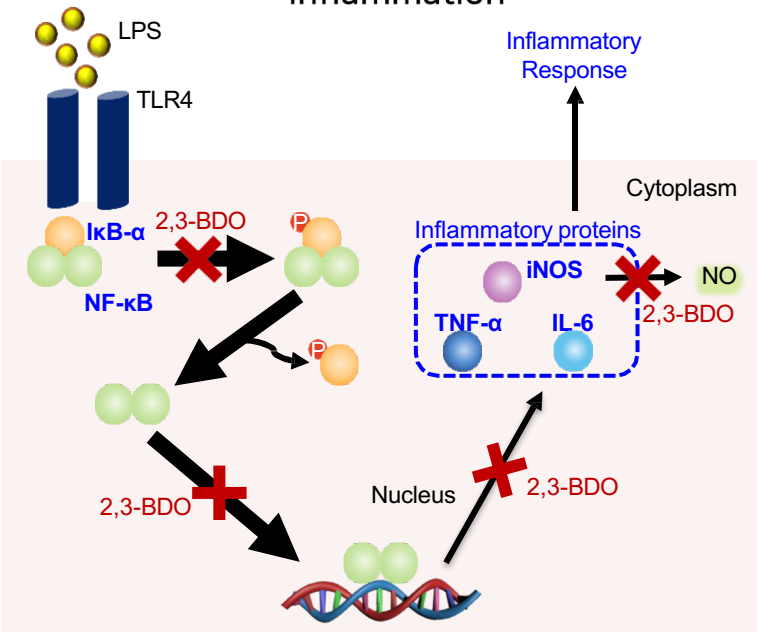
GreenDiol: The Greenest with Multi-functions

GreenDiol represses inflammation on skin

- 5 factors participating in inflammation on skin have been observed with GreenDiol and dexamethasone
- GreenDiol has also served anti-inflammatory effects like dexamethasone

GreenDiol shows a similar anti-inflammatory effect to steroids

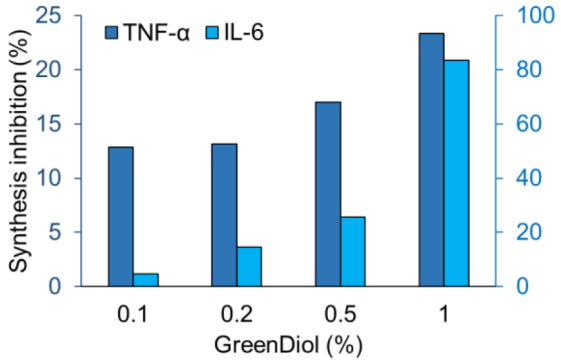
Mechanism of alleviating inflammation

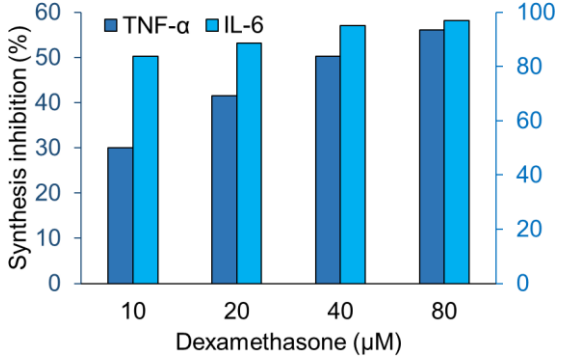


IκB-α : inhibitor of nuclear factor κB-α
NF-κB : nuclear factor κ-light-chain-enhancer of activated B cells
iNOS : inducible nitric oxide synthase
TNF-α : tumor necrosis factor-α
IL-6 : interleukin-6

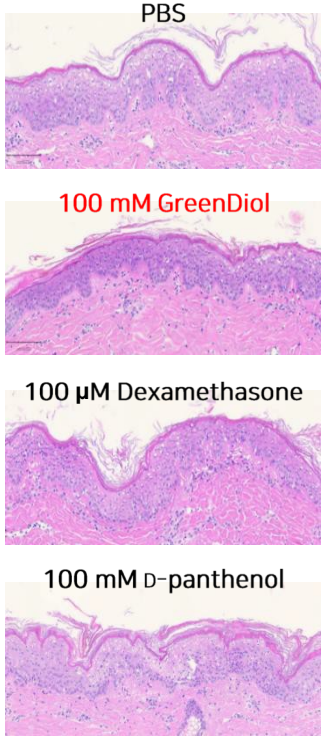
Manuscript in preparation

Effectiveness of GreenDiol on anti-inflammation





Ex vivo histological & immunological verification



*Pre-treated with 50 ppm PMA (phorbol 12-myristate 13-acetate)

GreenDiol: The Greenest with Multi-functions

Penetration of GreenDiol

1. Solubilization	- High solubility for active ingredients - Better solubilization of ceramides than 1,3-BDO (10x) & DPG (2x) - Better dispersion of dyes than 1,3-BDO
2. Unique texture	- Initial body texture - Quick absorption - Silky & less sticky
3. Stabilization	- Vitamin C stabilization - Alleviation of vitamin C discoloration
4. Anti-inflammation	- Reduction of redness - Inhibition of pro-inflammatory substances (NF-κB pathway)
5. Penetration	**- More effective penetration than 1,3-BDO (4x amount & 2x depth)**
6. Preservative boosting	- Superior preservative boosting than 1,3-BDO & 1,3-PDO (~20% more effective)
7. Moisturization	- Superior moisturizing capability than 1,3-BDO (8x) - Synergistic moisturizing effects with glycerin

GreenDiol: The Greenest with Multi-functions

GreenDiol more effectively penetrates dyes into skin and hairs than other diols

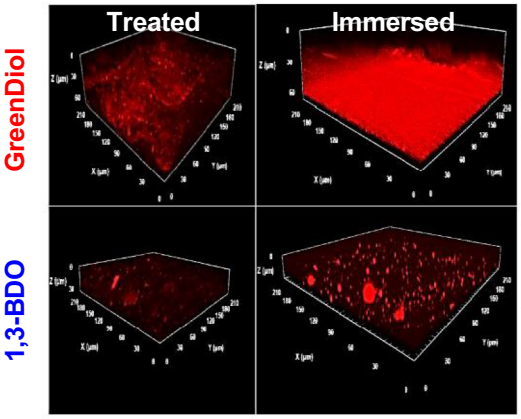
- The amounts of a dye in skin tissues that were treated with or immersed in GreenDiol have shown 4x or 10x higher than those of 1,3-BDO, respectively.
- A commercial color shampoo containing GreenDiol have shown remarkable hair-dying performance

GreenDiol can quickly dye the hair and retain the color longer for color shampoo

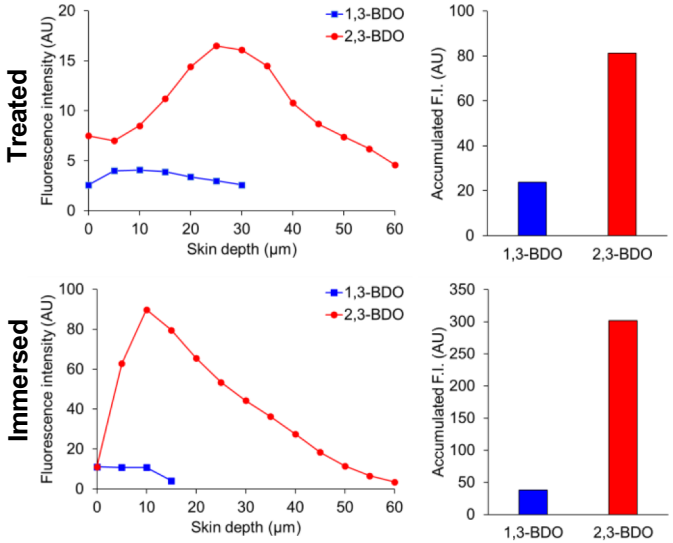
We have successfully developed a lipstick that lasts for 24 hours.

We could develop a color shampoo using GreenDiol for the first time.

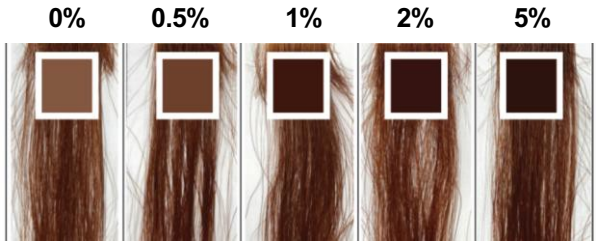
3D skin penetration & absorption



**CLSM image of fluorescent substances by skin depth*



Hair pigmentation (GreenDiol content)



Part	Trade name	INCI Name	Content (%)
A	Water	Water	Up to 100
	Carbopol AQUA SF-1	Acrylates copolymer	8.00
	NaOH	Sodium hydroxide	0.45
B	Mitain L	Lauryl betain	21.50
	Miconium CTAC-29	Cetrimonium chloride	8.50
	Eumulgin LM23	Laureth-23	1.00
	Micopol CIP	Cocamide MIPA	5.00
C	GreenDiol	2,3-Butanediol, Water	0.5~5
	Colorant	Colorant	0.70
D	Preservative	Preservative	q.s.

GreenDiol: The Greenest with Multi-functions

Preservative Boosting by GreenDiol

1. Solubilization	- High solubility for active ingredients - Better solubilization of ceramides than 1,3-BDO (10x) & DPG (2x) - Better dispersion of dyes than 1,3-BDO
2. Unique texture	- Initial body texture - Quick absorption - Silky & less sticky
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6. Preservative boosting	**- Superior preservative boosting than 1,3-BDO & 1,3-PDO (~20% more effective)**
7. Moisturization	- Superior moisturizing capability than 1,3-BDO (8x) - Synergistic moisturizing effects with glycerin

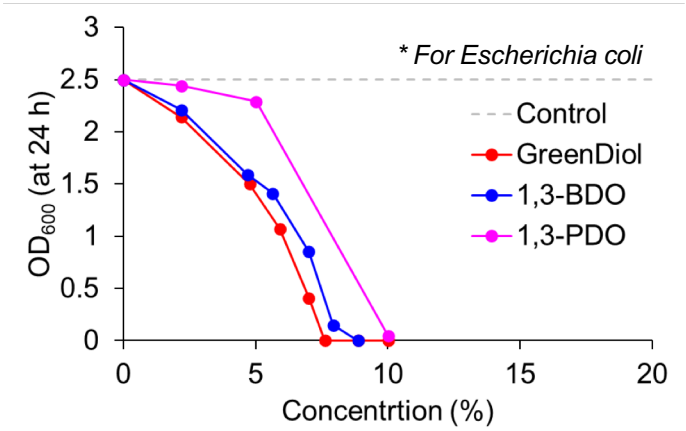
GreenDiol: The Greenest with Multi-functions

GreenDiol has a better preservative boosting effect compared with other polyols

- MIC test results show better preservative effect of GreenDiol than other diols
- In particular, GreenDiol boosts the effects of conventional preservatives (e.g. phenoxyethanol)

GreenDiol decreases the use of preservatives reducing irritation

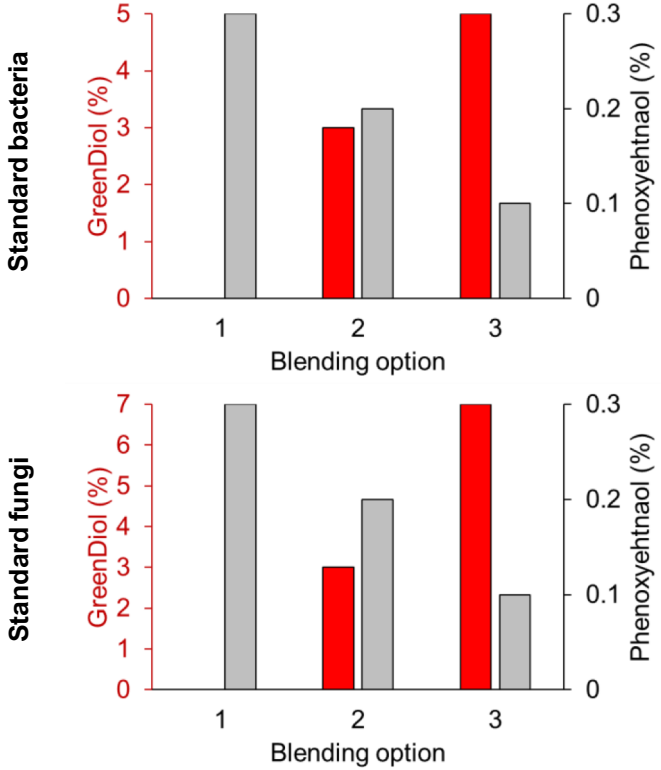
GreenDiol MIC test



Substance	15%	20%	25%
GreenDiol	×	○	○
1,3-BDO	×	×	○
1,3-PDO	×	×	○

** For bacteria: Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus*
For fungi: Aspergillus niger, Candida albicans

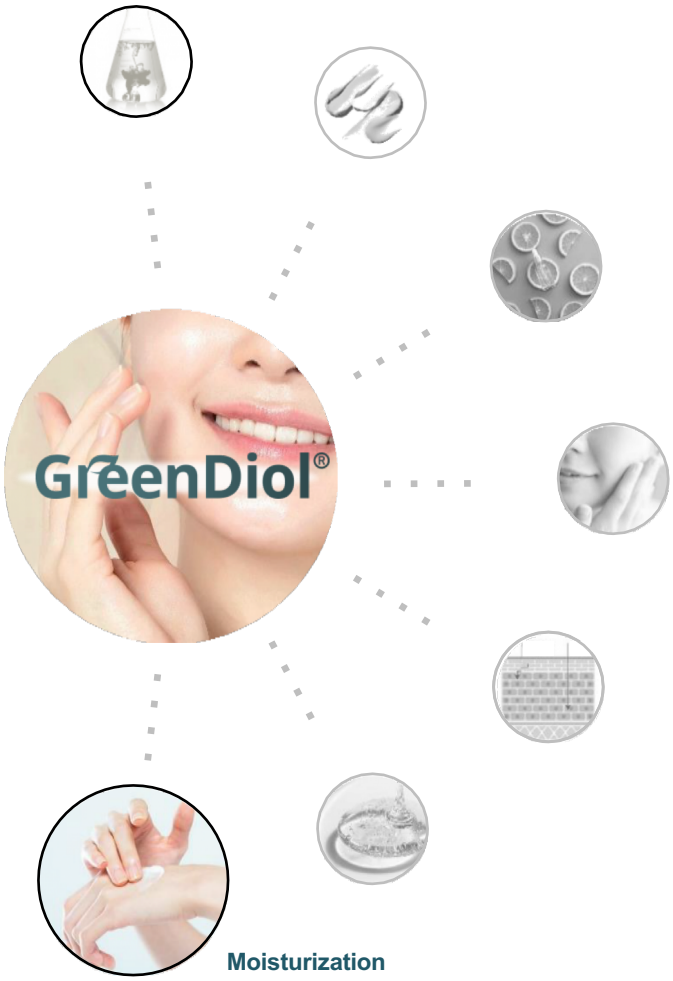
Preservative boosting effect



** Standard bacteria: E. coli, P. aeruginosa, S. aureus*
***Standard fungi: Aspergillus brasiliensis, Aureobasidium pullulans, C. albicans, Penicilliumm citrinum*

GreenDiol: The Greenest with Multi-functions

Moisturization by GreenDiol



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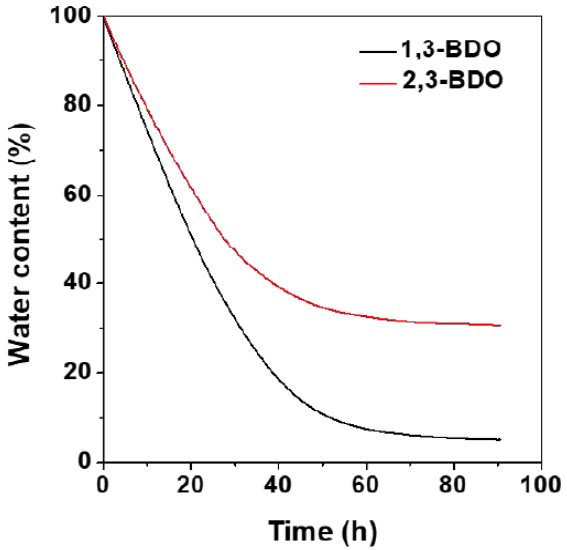
GreenDiol: The Greenest with Multi-functions

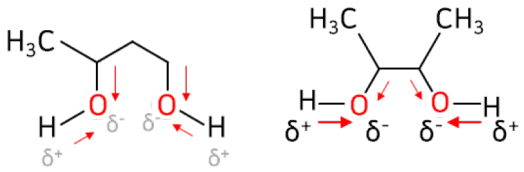
GreenDiol has higher water retention capability

- Higher polarities at the –OH groups of 2,3-BDO leads to higher water retention than other diols
- Unexpectedly, GreenDiol shows moisturization boosting effect with glycerin

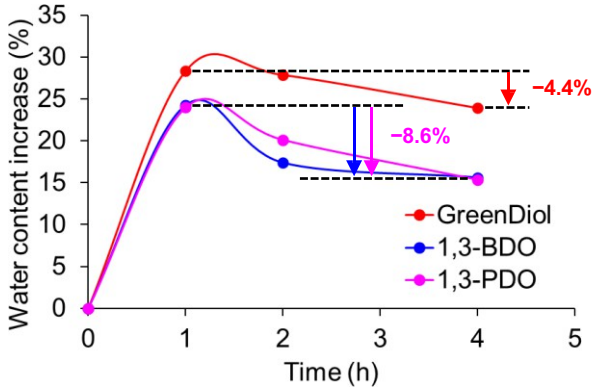
GreenDiol strengthens and lingers the moisturizing effect

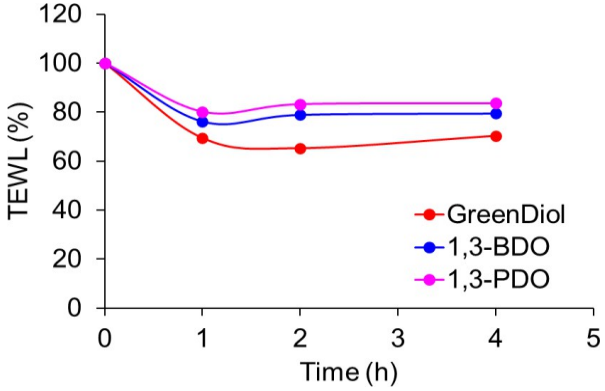
2,3-BDO moisturizing capability



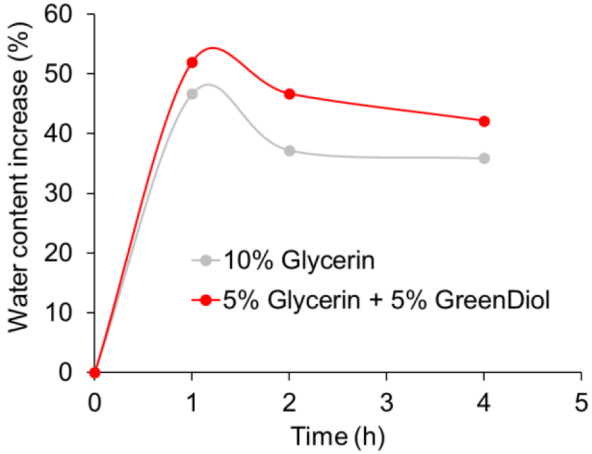


Water retention capabilities of diols





Moisturization boosting effect



**Reducing glycerin decreases skin irritation and improves the overall feel of the product.*

If you would like to discuss this report, please contact

GS Caltex Bio Solution Team

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choikr@gscaltex.com Kyeong Rok Choi