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Encapsulating Physical and Emotional Well-Being in Fashion Clothing

Wellness is fast emerging one of today's most powerful lifestyle trends. In 2002, world-renowned economist Paul Zane Pilzer estimated it to be \$200bn industry with potential to grow to over \$1 trillion annually by 2012 [1]. Growing consumer preoccupation with physical and emotional well-being has created an attractive, sustainable market space that has already stimulated new business growth in sectors as diverse as cosmetics, nutrition, health, leisure and travel. Research studies have confirmed that both men and women are excited by the concept of well-being benefits in clothes, especially those worn close to the body. A number of manufacturers and chemical companies have started offering range of health giving finishes and textiles treated with them. Fiber and fabric functionalities like protection, stretch, UV protection and enhanced thermal properties can also be combined with these specialized finishes to enhance the feeling of well being. The earliest example is that of Osaka based manufacturer Teijin which saw 2 million pairs of its Amino jeans- treated with arginine, an amino acid that is said to keep the skin youthful, disappear from stores in a pre-Christmas sale in 2002 in less than 24 hours [2].

Most wellness finishes on textiles use the time-tested technology of microencapsulation to deliver active ingredients like moisturizers, therapeutic oils, or

even insecticides through the clothes onto skin directly where they are absorbed by the dermis [29]. Human skin or dermis is made up of cells, blood vessels and nerves in an extra-cellular matrix composed of fibrillated protein formations (collagen, elastin, etc.), which provide resilience to stretching, and a colloidal gel substance, which fills up the spaces between all the different dermal components. This gel substance is chiefly composed of water, mineral salts and glycosaminoglycans.

Microencapsulation of chemical finishes and fragrances

Through microencapsulation process a liquid or solid substance can be encapsulated in sealed micro spheres of size 0.5-2000 microns. These spheres form a suspension of tiny droplets surrounded by a thin membrane/ polymeric wall protecting the active agent before it is released, and are applied to a fabric through a simple pad-dry sequence [3,29]. During wear, simple mechanical rubbing of fabric gradually ruptures the membrane releasing active agent for cosmetic, therapeutic, energy boosting, stress busting, moisturizing or deodorizing effects.

Microencapsulation technologies have only recently been really begun to be exploited [3-7]. Encapsulating phase-change materials (PCM) that absorb or release heat according to the conditions provide some interesting end uses [6,27]. Another interesting development is that of incorporating fragrances within the microencapsulated polymer spheres, allowing a gradual release of an appropriate fragrance for aromatherapy [5-7] for some unusual benefits like - uplifting/head clearing; relaxing, muscle easing, and clear thinking/confidence building. Opportunities are also opening up for health and wellbeing via use of body-care,

skin-care substances that can be absorbed by the skin [4-9]. Skin moisturisers and skin-cooling products, or even appropriate drug therapy could become important markets with an ageing population. Another application area is microencapsulating insect-repellents for protection against mosquitoes and other insects [6,10].

Phase-change materials for thermoregulation

The concept for the thermo-regulating skin temperature using microencapsulated PCMs was developed in the 1980s for the US National Aeronautics and Space Administration (NASA) for use in space suits [8]. It was never utilized for space suits and was subsequently licensed to Outlast Technologies for use in textile fibres and fabric coatings. Over 150 companies are using microencapsulated PCM today under license from Outlast technologies.

Phase-change materials utilize microencapsulated medium-chain length alkanes [4,6,8] with melting point in the vicinity of 30-32 degC. When the ambient temperature increases above this, the alkane melts and latent heat is absorbed thereby interrupting the increase in temperature of a garment. Once the ambient temperature falls the PCMs solidify and the latent heat is released providing a heating effect. The crystallization temperature of these alkanes is ~26 degC. Thus, PCMs can be used to provide a cooling or a heating effect in the garment microclimate depending upon the ambient temperature [27]. Called as Adaptive Comfort technology, these patented microencapsulated PCMs (termed Thermocules) are used in a wide variety of textile applications especially on garments for those parts of the body where extremes of temperature are most keenly

felt such as gloves, socks, hats, outdoor wear, e.g. vests, thermals, parkas, snowsuits and trousers and in household textiles such as blankets, duvets, mattresses and pillowcases.

Aromatherapy/fragrance release

Aromatherapy has entered into the lifestyle of many consumers as a well-being solution to the stressful life of the global village in which we all live. Aromatherapy utilises the controlled release of aromas or fragrances to promote feelings of comfort and well-being amongst users [4,7,8]. Fragrances are known to provide a broad spectrum of advantages when applied to performance apparel (Table 1) [7].

Microencapsulated peppermint by LJ Specialities, UK has an uplifting/head clearing and even muscle-easing effect which could be used for active sportswear, while lavender applied to bed sheets or pillow covers can relax and encourage sleep [7]. Clear thinking/confidence building fragrances like jasmine and rose could also find use in women’s formal wear. The potential applications are clearly varied and many.

Table 1 Aromatherapy benefits from common fragrances [7]

Active ingredients for Uplifting, anti-heavy legs	Grapefruit - The oil from grapefruit peel has reviving and activating effects.
	Lemon - Lemon oil supplies freshness and vitality to tired feet
	Peppermint - provides Uplifting, Clear thinking, Head clearing, Muscle easing

	Thyme - Oils from the herb thyme have antiseptic and deodorizing properties
Active ingredients for Energizing Aromatherapy	Menthol
	Orange - The essential oil from the skins of oranges is vitalizing and balancing
	Ginger - The ginger root provides a vitalizing oil that re-awakens the senses
	Rosemary - Derived from the leaves of the plant, rosemary oil is stimulating and regenerating
Active ingredients for Relaxing Aromatherapy	Valerian - Valerian is well known for its relaxing properties
	Amber tree resin oil - Amber trees are especially widespread in Asia. Their bark provides a relaxing and oriental smelling oil with healing properties
	Camomile – Relaxing and Sleep encouraging properties
	Jasmine – Well known for its Relaxing, Balancing, Confidence building and Aphrodisiac properties
	Lavender - Lavender oil derived from the flowers is balancing and relaxing

Recent advances in this field have been reported by NY based International Flavors and Fragrances (IFF) in the form of Sensory Perception Technology (SPT) microcapsules. SPT microcapsules are based on a chemical similar to melanin together with certain binders that create strong chemical links with the fibres to impart high durability to repeated domestic washing, and even ironing [12]. The

Woolmark company has recently started endorsing the use of SPT products for wool fabrics. SPT can also be used with ingredients that can repel or negate odours.

Quest International of UK has developed such a unique set of ingredients that is the equivalent to 'white noise' to tobacco smoke, which can be added to clothes via SPT [13]. Such treatments could be applicable to fibres and fabrics used for seats or carpeting, creating 'smart environments' which always smell fresh, e.g. in public transport systems [6].

Body-care textiles

Microencapsulated finishes can also be designed using active ingredients e.g. Aloe vera gels, that on coming in contact with the skin, transfer some active substance with a variety of body caring or well-being effects. Because people in the developed nations are living longer and acting younger (the so-called 'youthful ageing' effect) there is now also a demand for products which are designed to beautify and to combat ageing.

Japan, the powerhouse of innovation recognized the growth in this sector early on. A number of manufacturers have introduced supplements like amino acids, vitamins, xylitol and other food additives into fabric to maintain pH balance in the skin or keep wearers cool. Amino acid manufacturer Ajinomoto teamed up with major sports goods firm Mizuno Corp to develop the 'Amino Veil' brand. The amino acids in Amino Veil branded tennis and golf clothes dissolve into wearer's perspiration, enhancing the material's ability to absorb moisture and keep the skin's pH (potential of

hydrogen) level balanced. The amino acid used in the product above is arginine, which helps to regenerate skin [29].

Clothing manufacturers and food ingredient companies are hoping to boost profits with several new inventions. Sports clothing firm Yonex has launched a range with xylitol, the sweetener more commonly found in chewing gum. It absorbs heat when it comes into contact with water and is said to offer a cooling effect. Thus, xylitol-enhanced jeans can keep the wearer cooler if she or he begins to sweat. Yonex Xylitol-impregnated Very Cool Polo Shirts lower body heat by 3 degrees for more comfort during the heat of play [29]. This new Yonex development in high-tech sportswear is worn by tennis stars Monica Seles, Elena Dementieva, David Nalbandian, Jelena Dokic and by badminton's leading tournament players.

Fuji Spinning, another major Japanese textile maker recently test-marketed women's T-shirts that were covered in pro-vitamin C, a liquid chemical that turns into real vitamin C when it touches the skin. The material boasts of providing enough amount of vitamin C as one would find in two lemons. And it holds enough vitamin content for about 30 washes [11, 29]. Though it is still not clear that the vitamins are actually absorbed into the skin or that the clothing will do you any good, but blouses, T-shirts and men's shirts made with this "V-Up" technology are already available at the Takashimaya department store in Tokyo. While vitamin C easily dissolves in water, Pro-vitamin C is water-resistant but is dissolved by sebum, an oily secretion our bodies produce naturally. As humans constantly produce sebum and sweat, dried pro-vitamin C fixed in the shirt's fibres naturally returns to liquid and attaches to the skin.

The problem of cellulite, thought to occur in some 85% of women, is considered to be caused by poor microcirculation. Sensory Perception Technology utilises kelp bladderwrack as an iodine source which is easily absorbed into the epidermis [12]. This speeds up the micro-circulation, stimulating glands and the connective tissues. This is claimed to fight the root causes of cellulite. Worn for long periods of time next to the skin in hosiery and underwear, kelp can also be applied with Aloe vera to promote an anti-cellulite effect. SPT microcapsules with Vitamin E has been used on walking socks for its blister healing effects and also applied along with Aloe vera and kelp to underwear/hosiery to help fight the effects of stretch marks (i.e. for maternity wear). Vitamin E action is basically considered to be that of a powerful anti-oxidant, protecting skin cells against the damaging effects of free radicals which age the skin.

Cognis Performance Chemicals of Germany has introduced their Skintex Care System, termed 'Wellness to Wear'. In the patented Skintex System, active ingredients are microencapsulated using chitosan, a substance made from the shells of shrimps in order to turn a simple garment into one termed an 'active-wellness' garment [6]. The active ingredients are delivered by three separate means - by friction between the microcapsules in the fabric and the skin; or the natural biopolymer membrane of the microcapsules would be biodegraded by enzymes naturally present in the skin; or, when the microcapsule biopolymer membrane (which is insoluble at pH 6–7) comes into contact with human skin (at pH 4–5) the membrane dissolves, thereby delivering the active substance.

The chemicals are a blend of essential oils and the finish can be applied by exhaustion onto the fabric during wet processing. The finish can be applied on hosiery, underwear and sportswear made from cellulosic fibres and all other fibres and blends and is claimed to last over several domestic washing cycles. More recently, Cognis has launched Skintex Reloading, to meet the consumer demand for long-lasting effects by making it possible to recharge textiles with new microcapsules. Skintex Reloading is available for the slimming effect, using care ingredients such as Shea butter, apricot kernel oil, rose hip oil and red algae extract.

Table 2. A representative Skintex® range of essential oil blends by Cognis performance chemicals [14, 29].

Active ingredients for Cooling	Myritol® - Helps to protect the skin from drying out and achieves a velvety soft and supple feeling
	Menthol - Mostly derived from peppermint oil, Menthol is well known in the food and skincare industry for its cooling and refreshing properties
Active ingredients for Moisturizing	Squalane - Derived from olive oil, this ingredient balances the moisture and fat content of skin
	Vitamin E - Vitamin E protects skin from free radicals and premature ageing
	Monoï de Tahiti - A moisturizer combining highly refined coconut oil and Tahitian Tiare flower, it supports the regeneration of skin cells

	Passion fruit Oil - A tropical fruit oil which is well known for its skin relaxing and smoothing properties
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International Flavors & Fragrances (IFF) with Invista™ (previously DuPont Textiles & Interiors) launched a collection of Body Care range that will deliver cosmetic and well-being benefits like freshness, moisturizing and massage for leg wear and intimate apparel. The massage properties are used in Yoga lines, as a result of combining textile compression technology and temperature management in special high-tech hosiery yarns. Legs stay cool in summer and warm in winter, and are toned and invigorated all year round by a gentle massaging action that works vitamin-rich nutrients into the skin. Body Care also uses Schoeller Outlast phase-change technology for body temperature regulation.

Ohara Paragium Chemical is offering natural skincare & healthcare finishing agents based on combination of an Amino-acid-based softening agent that can produce unconventional, less-sleek but full, elegant silky hand and a number of innovative finishing agents that produce moisture retaining, slimming or anti-ageing (anti-oxidation) effects [29]. Active ingredients used are - the fat-burning effect of *capsaicin*, the moisture-retaining and skincare effect of raspberry and *squalane*, and high anti-oxidation properties of rice germ oil containing ferulic acid and γ -oryzanol, along with vitamin E. Vitamin E is known to be anti-oxidation vitamin and is used as a generic term for fat-soluble tocopherols.

Cosmétel is offering Beautiva® range of body-care pre-treated panty hose, hose, knee-highs, lingerie or socks targeted at busy women who have little time to devote to caring for their skin and figure [29]. The fabric of the garment is impregnated with the active ingredient, which is released by the warmth of the skin when the garment is worn. Garments may be worn for periods extending from several days to several weeks, depending on the specific objective (moisturize, relax, slenderize). The natural active ingredients used are - *cyclotella*, a microalga that works on fat metabolism, promotes lymph circulation and helps resorb cellulite; and another microscopic algae *Padina pavonica*, an extremely effective anti-age ingredient. The specific action continues even through several washings. It can be restored thanks to the mini-doses or spray included with the garment "re-impregnating" the fabric with the mini-dose.

Antimicrobial and deodorising finishes

Feeling fresh is important to ones wellbeing. Freshness is about smells and making garments fresh usually means getting rid of unpleasant smells that are mainly generated through human sweat as the result of perspiration. Human body perspires continuously and the sweat is dispersed as liquid over the skin's surface, from where it can evaporate. The major component of human sweat is water; however, it is actually a cocktail of various minerals, fatty acids, toxins, and other by-products of an individual's metabolism and the foods consumed. On the skin surface, sweat meets bacteria which feed on the fatty acids that are expelled along with perspiration. Human body is known to host up to two kilograms of bacteria, of which a number of different kinds is found on skin [26]. In the hot and humid skin conditions provided by

the micro-climate between the skin and the garments, the bacteria grow rapidly, consuming fatty acids and decomposing sulphur and nitrogen compounds in the process. The leftovers of this decomposition process consist of small, volatile molecules that 'float' in the air, are caught by human noses and provide the 'smell'. Keeping fabrics to maintain that just-washed 'fresh' feel longer would therefore require specialized finishes that would control these unpleasant odours. Garments such as intimate apparel, socks, gloves and especially textile products used in footwear clearly offer a large potential market for retention of freshness during wear. Other areas include household textiles, e.g. carpets, curtains, cushions, etc., as well as textiles used in automobiles and aircrafts such as seat covers and floor coverings [14-17, 28]. Another important area is that of performance sportswear for all manner of physical activities.

A number of specialized finishes have been introduced in recent times in the market to control unpleasant odours [18,23,24]. They operate by employing either of two mechanisms i.e. by absorbing or simply preventing odours from forming.

Most odour absorbing finishes available are based on the special chemically build-up ring-shaped sugar compounds, the so-called cyclodextrines. With a suitable reactive group, β -cyclodextrin could be covalently bound to cotton [21] and act as a renewable source of odour-entrapment. Once the storage capacity is occupied, a washing can renew the storage function. As the threat of global warming looms large, and if garments are required to be washed less frequently then use of such finishes will decrease environmental pollution.

The other set of finishes operate by preventing the formation of odour itself through use of antimicrobial agents. Though many antimicrobials are available for use in the textile industry, for this specific use it is imperative that the agents are compatible with skin and the environment. It is often argued that chemical substances having a germicidal effect on the textile can also influence the natural flora of the human skin. The German Federal Ministry of Health has issued a warning against the carefree usage of antibacterial products in household and textiles. Odour preventing finishes have therefore been so far limited to use of one of the three approaches: (a) use of nano dispersions of silver compounds [22]; (b) use of Chitosan - an effective natural antimicrobial agent derived from Chitin, a major component in crustacean shells; and (c) use of natural herbal antimicrobial finishes since, there is a tremendous source of medicinal plants available with antimicrobial composition [14-17].

Microencapsulated antimicrobial agents provide a long-term controlled release effect that could be utilised to prevent the growth of bacteria in textiles that can give rise to undesirable odours. With the increasing resistance of microbes to antibiotics, considerably more interest is now being shown in the antimicrobial properties of essential oils such as tea tree oil, eucalyptus and clove. Essential oils are generally volatile and will rapidly evaporate from surfaces. Microencapsulation minimises evaporation and greatly extends the shelf life. Besides essential oils, several natural medicinal plants are available with antimicrobial composition. Antimicrobial properties of dyed fabric have been reported with many natural dyeing materials like *Terminalia Chebula*, *Acacia*, *Catechu* and *Quercus infectoria* [30]. Cotton fabric treated with tannin-rich extract of *Quercus infectoria* (QI) plant in combination with alum & copper mordants showed good activity at 12% concentration (owf), inhibiting

the microbial growth by 70-90%. The study also shows that the cotton textiles can be successfully treated with QI to produce bioactive textiles from natural ecofriendly materials and that QI is a viable alternative to synthetic antimicrobial agents for use in hospital textiles and an effective anti-odour agent for use in sports and household textiles.

Tea tree oil, a member of the Eucalyptus family containing over one hundred different compounds possesses natural antibacterial and antifungal properties. It has been shown to be effective against a wide variety of bacteria [6]. Microencapsulated antimicrobial agents are also used to fight against methicillin-resistant *Staphylococcus aureus* (MRSA) infections. Micap plc of UK has developed a mixture of three essential oils, combined in a specific ratio, which are microencapsulated and applied in a gelatine base to the wound dressing [19].

The use of antimicrobials can also be used to prevent infections [6]. There is also the prospect of controlled release of antibiotics from textiles in contact with the skin for controlling the post-operative infections after surgery [20]. Surgical sutures containing microencapsulated antibiotics could give a controlled release of antibiotic around the site of the surgical incision speeding patient recovery and preventing post-operative infection in the first few important days after surgery.

Insect-repellent and insect-resist treatments

For apparel designed to be worn in tropical climates where mosquitoes abound there is clearly a market for insect-repellent treatments that have a long-lasting effect.

Microencapsulated insect-repellent agents are employed to provide a longer lasting controlled release effect. Active ingredients used as mosquito repellent include N,N dimethyl-m-toluamide (DEET), permethrin, pyrethrum and essential oils [25]. The natural organic ester plant oils act effectively as a nerve agent on insects but more importantly recent research has shown that these have an unusual effect on mosquitoes of jamming their mechanism of homing on to their victims. As a result microencapsulated release of these plant oils has been shown to significantly decrease the bites per minute in test boxes from 50 to virtually none.

The microencapsulated insect-resist treatments have also been used for textiles containing natural protein fibres-like wool and silk. Such finishes could provide long-term protection against the larvae of moths and many types of beetles [16-17].

Conclusion

The wellness business is proactive. People voluntarily become consumers – to feel healthier, to reduce the effects of ageing, and, to avoid becoming consumers of the sickness business. Wellness clothing offers a new challenge to design students and field is wide open to innovation.

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